UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 775

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. ▼ June 3, 1919

COMMERCIAL PRESERVATION OF EGGS BY COLD STORAGE

By

M. K. JENKINS, Assistant Bacteriologist. Prepared under the direction of M. E. PENNINGTON, Chief, Food Research Laboratory

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SOME ASPECTS OF THE COLD STORAGE BUSINESS.

The preservation of eggs by means of cold renders one of the most important of the perishable foods available at all times. According to Holmes,[2] about 50 per cent of the egg crop is produced during the months of March, April, May, and June, and 86 per cent of the eggs held in storage are stored in March, April, and May. During these cool months the eggs are the freshest and most desirable for storing. According to a statement issued by the Bureau of Markets, April 15, 1918, 478 warehouses, which report holdings of eggs in cold storage, are fairly well distributed over the United States. The March 11, 1918, summary report, issued by the Bureau of Markets, shows that a total of 6,595,850 30-dozen cases, valued at $70,487,212, were stored in 396 houses during the season of 1917–18. These figures, although lower than the actual amounts, due, as mentioned in the reports, to the failure of a few houses to forward state-

[1] The work covered in this bulletin was done in the Bureau of Chemistry. In the future, the marketing phases of the Department's work on poultry and eggs will be conducted by the Bureau of Markets, under a cooperative arrangement with the Bureau of Chemistry.
[2] U. S. Dept. Agr., Statistics Bul. 93.

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ments of their holdings, give a fair approximation of the extent and value of the business.

The deliveries in appreciable quantities of eggs from cold storage begin in August, continue in increasing amounts during the fall and early winter months, and gradually decrease from this period until the first of March, when there are but few, or practically no eggs left in storage in normal seasons. For example, during the season of 1916–17 57.7 per cent of the holdings were left in storage on November 1, 34.2 per cent on December 1, 13.8 per cent on January 1, 2.1 per cent on February 1, and 0.1 per cent on March 1.[1] These statistics agree with those collected by Holmes [2] several years earlier. The increase in consumption of cold storage eggs during the winter corresponds to the marked decline in egg production during that time.

PURPOSE OF THE INVESTIGATION.

Although a number of publications discuss the losses in eggs which follow the routine course of marketing without the intervention of cold storage,[3] comparatively few data, showing the changes and losses in different grades of eggs handled according to commercial usages during various holding periods in cold storage, are available. This investigation was made primarily to determine the efficiency of the preservation of commercial eggs by cold storage. The following phases of the problem were studied:

(1) The relative keeping quality of fresh, heated, sound, dirty, and cracked eggs.

(2) The relation of the month of storage to preservation.

(3) Efficiency of the commercial grading of eggs for cold storage.

(4) Analysis of bad eggs developing in commercially packed eggs during storage.

(5) Relation of care in initial grading to the development of bad eggs during storage.

(6) Rate of evaporation of moisture from eggs.

(7) Rate of absorption of moisture by case and fillers.

(8) Physical and chemical changes in eggs during storage.

(9) Absorption of foreign flavors during storage.

GENERAL PLAN OF INVESTIGATION.

The eggs used in these observations were produced in the Corn Belt States of the Middle West, with the exception of a few lots which came from Kentucky. They were shipped East in refrigerator cars, and were from three to seven days en route. As soon

[1] Report of the Bureau of Markets issued Apr. 1, 1917.

[2] U. S. Dept. Agr., Statistics Bul. 93.

[3] U. S. Dept. Agr. Buls. 51, 224, 664; U. S. Dept. Agr., Bur. Chem. Circs. 83, 104; U. S. Dept. Agr., Yearbook (1910) Article 552, and Yearbook (1914) Article 647.

as received they were transferred to a commission house equipped with chill rooms, a candling and breaking room, all of which were refrigerated. Here the observations were made before the eggs were stored, as well as on removal from storage at various intervals during the storage period. The examination of the different classes of eggs to determine the relative deterioration consisted in determining the quality of the eggs in the shell by candling and out of the shell by appearance, odor, and chemical analysis. It was necessary to grade the eggs after they were opened because there are certain classes of bad eggs that can not be recognized and others which are frequently missed by grading in the shell.[1] The method of separating the edible and inedible eggs by candling [2] and breaking [3] was the same as that followed commercially in up-to-date candling and breaking rooms. The inedible eggs detected by candling correspond to those found by the dealers in grading eggs for market, and the bad eggs detected by breaking represent those that would be found when the eggs were opened by the consumer. Samples for laboratory examination were taken from the liquid product obtained on mixing the eggs graded as edible. Observations were made on 9 lots which were received and stored in New York City, and on 12 lots delivered to and stored in Philadelphia. The eggs were stored at a temperature of from 30° to 33° F. in rooms used commercially for the cold storage of eggs in the shell (Pl. I). During this investigation 841 30-dozen cases of eggs of varying grades were examined before and after storing. The history of the different lots under observation is reported in detail in Table 1.

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[1] U. S. Dept. Agr. Bul. 702. [2] U. S. Dept. Agr. Bul. 565. [3] U. S. Dept. Agr. Bul. 391.

TABLE 1.—*History of samples.*

Experiment No.	Cases examined.	Grade of eggs.	Kind of pack.	Origin of shipment.	Date shipped.	Date received.	Date in storage.	Location of cold storage.
41680	55	April firsts	Commercial	Mattoon, Ill.			Apr. 9, 1914	New York.
41896	36	do	do	Casey, Ill.		Apr. 10, 1915	Apr. 17, 1915	Philadelphia.
41897	12	do	Careful	do		do	do	Do.
41933	27	do	Commercial	Dietrich, Ill.	Apr. 6, 1916	Apr. 10, 1916	Apr. 29, 1916	Do.
41934	9	do	Careful	do	do	do	do	Do.
41716	55	May firsts	Commercial	Mattoon, Ill.			May 9, 1914	New York.
41916	33	do	do	Louisville, Ohio	May 10, 1915	May 13, 1915	May 22, 1915	Philadelphia.
41917	11	do	Careful	do	do	do	do	Do.
41936	48	do	Commercial	Manchester, Iowa	May 13, 1916	May 19, 1916	May 26, 1916	Do.
41937	8	do	Careful	do	do	do	do	Do.
41782	40	June firsts	Commercial	(1)			June 5, 1914	New York.
41918	30	do	do	Anderson, Ind	June 3, 1915	June 7, 1915	June 18, 1915	Philadelphia.
41920	10	do	Careful	do	do	do	do	Do.
41941	27	do	Commercial	Harrodsburg, Ky	June 8, 1916	June 15, 1916	June 22, 1916	Do.
41942	9	do	Careful	do	do	do	do	Do.
41787	30	July firsts	Commercial	Illinois			July 6, 1914	New York.
41922	27	do	do	New Madison, Ohio	June 26, 1915	June 30, 1915	July 27, 1915	Philadelphia.
41927	9	do	Careful	do	do	do	do	Do.
41945	27	do	Commercial	(2)			July 17, 1916	Do.
41946	9	do	Careful	(2)			do	Do.
41679	55	April dirty eggs	Commercial	Mattoon, Ill.			Apr. 9, 1914	New York.
41935	9	do	Careful				Apr. 29, 1916	Philadelphia.
41686	55	May dirty eggs	Commercial	Mattoon, Ill.			May 6, 1914	New York.
41778	35	June dirty eggs	do	Chicago, Ill			June 5, 1914	Do.
41943	30	do	do	Abilene, Kans		June 1, 1916	June 22, 1916	Philadelphia.
41944	9	do	Careful	do		do	do	Do.
41805	30	July dirty eggs	Commercial	(1)			July 13, 1914	New York.
41919	30	June seconds	do	Harrodsburg, Ky	June 8, 1915	June 14, 1915	June 25, 1915	Philadelphia.
41921	10	do	Careful	do	do	do	do	Do.
41788	30	July seconds	Commercial	Illinois			July 6, 1914	New York.
41923	27	do	do	Kansas City, Mo	June 28, 1915	July 2, 1915	July 30, 1915	Philadelphia.
41928	9	do	Careful	do		do	do	Do.

1 Purchased on New York market.

2 Purchased on Philadelphia market.

RESULTS OF THE INVESTIGATION.

EFFECT OF CONDITION OF SHELL UPON PRESERVATION.

The losses in commercial fresh eggs with clean, sound shells were found to be negligible during a storage period of 11 months. In the experiment reported in Table 2 and figure 1, the bad eggs detected by candling and breaking did not amount to more than five eggs per case at any time during the storage period. The principal types of bad eggs found were green whites, crusted yolks, moldy eggs, mixed rots, and white rots (Table 3). The first two types mentioned are characteristic of washed eggs after storing. Unfortunately it is not possible to detect all washed eggs by inspection of the shell before storing.

If the shell of a fresh egg is dirty its liability to spoilage during holding in cold storage is markedly increased. A typical lot stored in April showed on monthly withdrawals from storage from September to March, inclusive, from 12 to 30 bad eggs per case by candling and from 10.5 to 29 additional by breaking (Table 2 and fig. 1). Among commercial dirty eggs are found eggs soiled with feces, mud, and blood, as well as stained eggs showing evidence of having been washed or having come in contact with the wet, muddy feet of hens or wet nests. Bacteria and molds can penetrate wet shells, even though unbroken, and cause the egg to rot. Moldy eggs, green whites, crusted yolks, mixed rots, white rots, and black rots are the principal varieties of bad eggs among dirty refrigerator eggs (Table 3).

It is generally known that eggs with damaged shells will not keep in storage. This is strikingly shown in Table 2 and figure 1. The most common form of deterioration of the cracked egg is through molding, which, in stocks stored in spring, becomes pronounced in September and October, and increases throughout the storage period (Table 4). The bad eggs developing in cracked eggs stored in April and May varied, as found by candling and breaking, from 44 per case in September to 144 per case in March. If the shells were dirty in addition to being cracked, the losses were greater, amounting in eggs stored in April and held until December to as high as 211 to the case as found by candling (Table 2 and fig. 1). These observations were made on damaged eggs present in first-grade commercial packages through oversight or carelessness during the initial sorting of the eggs for storage. The losses found would have been higher had the observations been made on cases containing only cracked eggs, for the mold growing on one egg readily spreads to other broken eggs (Pl. II).

These studies emphasize the importance of selecting only eggs with clean, sound shells for storing.

TABLE 2.—*Effect of condition of shell upon preservation of fresh eggs.*

Month of withdrawal.	Clean, sound shells.			Dirty, sound shells.			Clean, cracked shells.			Dirty, cracked shells.	
	Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case by candling.
		Candling.	Breaking.		Candling.	Breaking.		Candling.	Breaking.		
April	......	......	......	360	0	11	59	0	12	86	0
May	1,026	0	0.5	......	......	......	......	......	......	......	......
June	......	......	......	......	......	......	......	......	......	50	0
July	......	......	......	......	......	......	......	......	......	80	22.5
August	......	......	......	359	9	16	49	22	7.5	104	36
September	710	0	2.5	355	16	15	81	26.5	17.5	158	71.5
October	704	1	1.5	354	12	22.5	58	87	18.5	65	160
November	695	0.5	2	353	21	13.5	73	108	10	114	109
December	709	0.5	1	357	15	21	85	84	21	82	211
January	694	0	2.5	358	18	29	60	132	12	......	......
February	715	1	2	355	30	10.5	82	92.5	21	91	224
March	717	2.5	2.5	358	24	17	45	136	8	......	......

TABLE 3.—*Varieties of bad eggs developing during storage in eggs with sound shells sorted from commercial refrigerators.*[1]

FOUND BY CANDLING.

Kind.	April firsts.		May firsts.		June firsts.		July firsts.		April dirty eggs.		May dirty eggs.		June dirty eggs.		June seconds.		July seconds.	
	No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
Mixed rots	50	25.38	57	25.22	154	44.90	388	52.65	19	7.20	66	11.32	163	40.95	130	32.99	125	40.45
White rots	20	10.15	33	14.60	42	12.24	125	16.96	24	9.09	57	9.78	46	11.56	70	17.76	30	9.71
Black rots	13	6.60	29	12.83	19	5.54	38	5.16	34	12.88	182	31.21	22	5.53	30	7.61	14	4.53
Moldy eggs	88	44.67	72	31.86	93	27.11	138	18.72	140	53.03	177	30.36	129	32.41	122	30.96	110	35.59
Crusted yolks	25	12.69	34	15.04	34	9.91	47	6.37	45	17.04	101	17.32	38	9.55	42	10.66	30	9.71
Bloody whites	1	0.50	1	0.44	1	0.29	1	0.13	2	0.76	......	......	......	......	......	......	......	......
Total	197	......	226	......	343	......	737	......	264	......	583	......	398	......	394	......	309	......

FOUND BY BREAKING.

Green whites	41	53.25	61	42.66	88	31.73	83	30.97	20	33.33	43	23.37	100	51.55	74	23.12	65	28.51
Bad-odor eggs	4	5.20	15	10.47	18	6.50	15	5.60	12	20.00	34	18.48	12	6.19	57	17.81	12	5.26
Mixed rots	14	18.18	49	34.27	133	48.01	143	53.36	7	11.66	48	26.09	61	31.44	167	52.19	124	54.39
White rots	1	1.29	1	0.70	2	0.72	......	....	7	11.66	7	3.80	1	0.51	6	1.88	......	....
Moldy eggs	2	2.60	4	2.80	21	7.58	3	1.11	......	....	3	1.63	......	....	8	2.50	6	2.63
Crusted yolks	15	19.48	12	8.40	15	5.42	23	8.58	14	23.33	49	26.63	20	10.31	8	2.50	21	9.21
Bloody whites	......	....	1	0.70	......	....	1	0.37	......	....	......	....	......	....	......	....	......	....
Total	77	....	143	....	277	....	268	....	60	....	184	....	194	....	320	....	228	....

[1] Data from cases of eggs withdrawn from storage from November to March.

TABLE 4.—*Varieties of bad eggs developing during storage in eggs with cracked shells sorted from commercial refrigerators.*[1]

FOUND BY CANDLING.

Kind.	April firsts.		May firsts.		June firsts.		July firsts.		April dirty eggs.		May dirty eggs.		June dirty eggs.		June seconds.		July seconds.	
	No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
Mixed rots	22	8.30	41	14.54	21	11.35	52	13.27	3	1.44	16	5.18	55	17.19	33	17.64	30	13.64
White rots	7	2.64	12	4.26	9	4.86	27	6.89	9	4.30	22	7.12	24	7.50	16	8.56	24	10.91
Black rots	1	0.38	10	3.54	3	1.62	10	2.55	7	3.35	34	11.00	7	2.19	4	2.14	4	1.82
Moldy eggs	231	87.17	216	76.60	150	81.08	298	76.01	183	87.56	217	70.22	221	69.06	130	69.52	157	71.36
Crusted yolks	4	1.51	3	1.06	2	1.08	5	1.28	7	3.35	20	6.47	13	4.06	4	2.14	5	2.27
Total	265	....	282	....	185	....	392	....	209	....	309	....	320	....	187	....	220	....

FOUND BY BREAKING.

Kind.	April firsts.		May firsts.		June firsts.		July firsts.		April dirty eggs.		May dirty eggs.		June dirty eggs.		June seconds.		July seconds.	
Green whites	17	47.22	7	29.17	5	26.31	13	27.08	......	....	......	....	13	48.15	8	36.36	32	49.23
Bad-odor eggs	3	8.33	2	8.33	2	10.53	5	10.42	......	....	......	....	5	18.52	4	18.18	18	27.69
Mixed rots	7	19.44	14	58.34	9	47.37	22	45.83	......	....	......	....	6	22.22	5	22.73	11	16.92
White rots	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	1	1.54
Moldy eggs	7	19.44	......	....	2	10.53	5	10.42	......	....	......	....	2	7.41	2	9.09	......	....
Crusted yolks	2	5.56	1	4.16	1	5.26	3	6.25	......	....	......	....	1	3 70	3	13.64	3	4.61
Total	36	....	24	....	19	....	48	....	......	....	......	....	27	....	22	....	65	....

[1]Data from cases of eggs withdrawn from storage from November until March

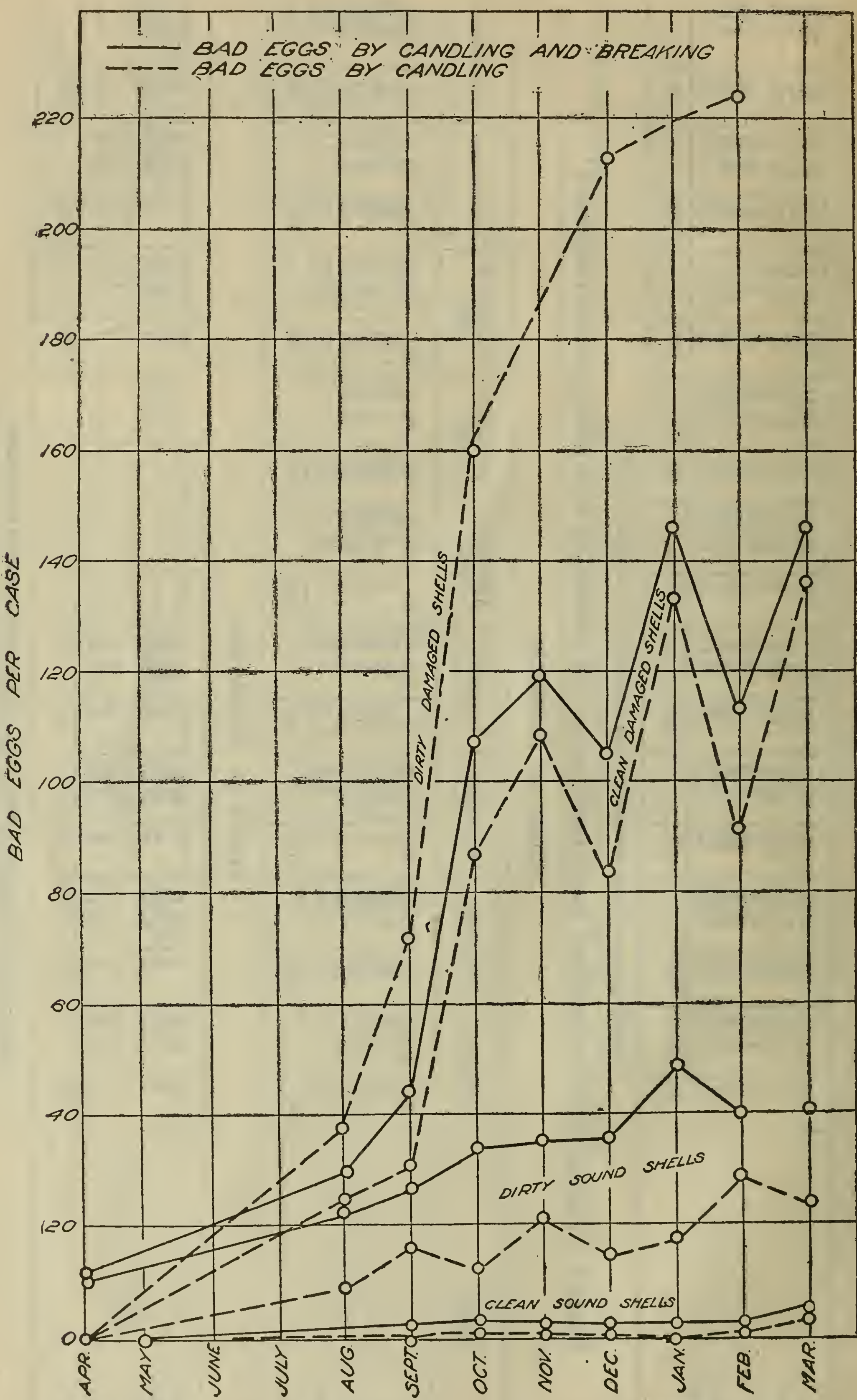
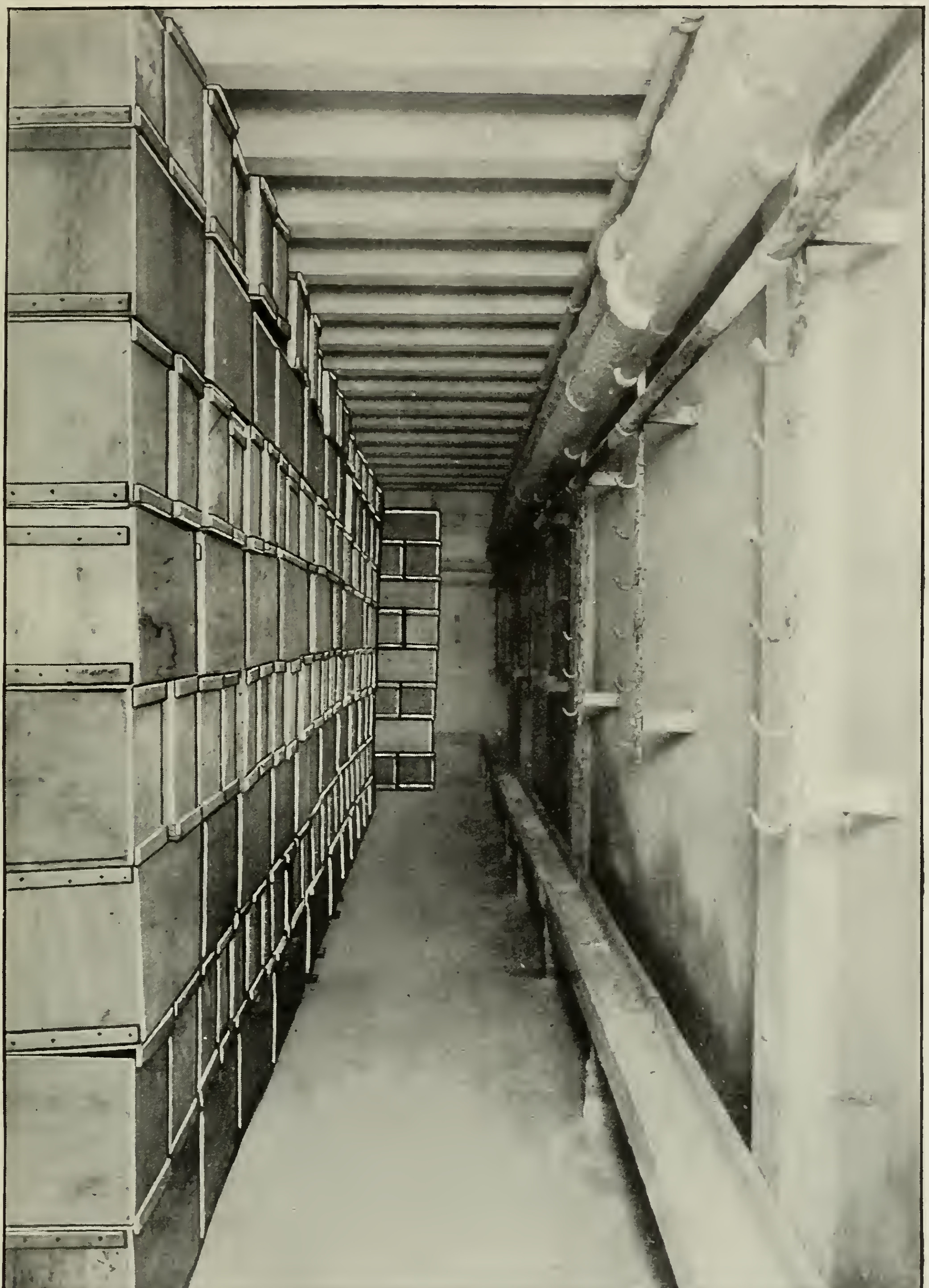
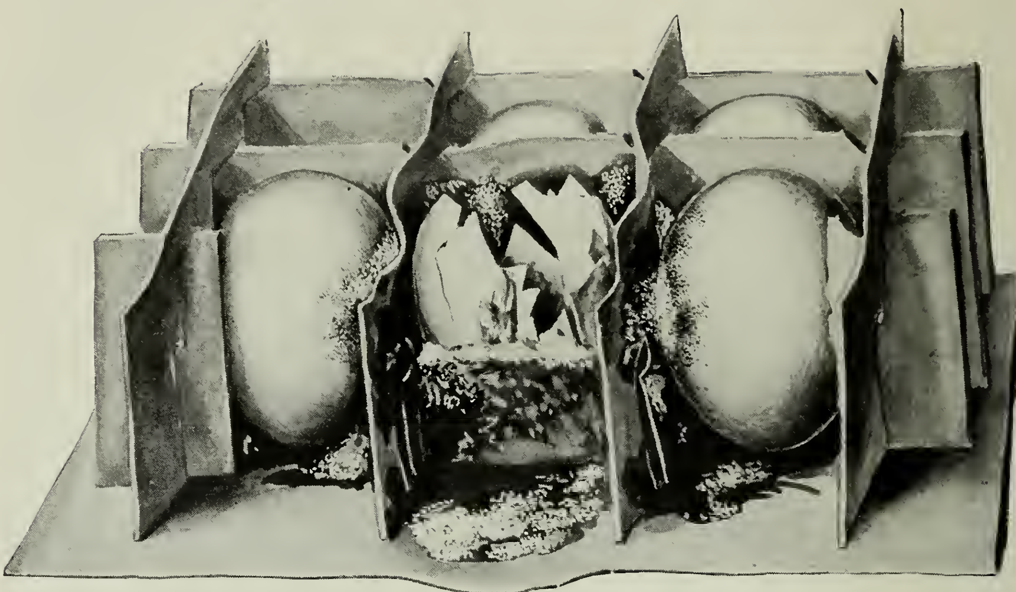


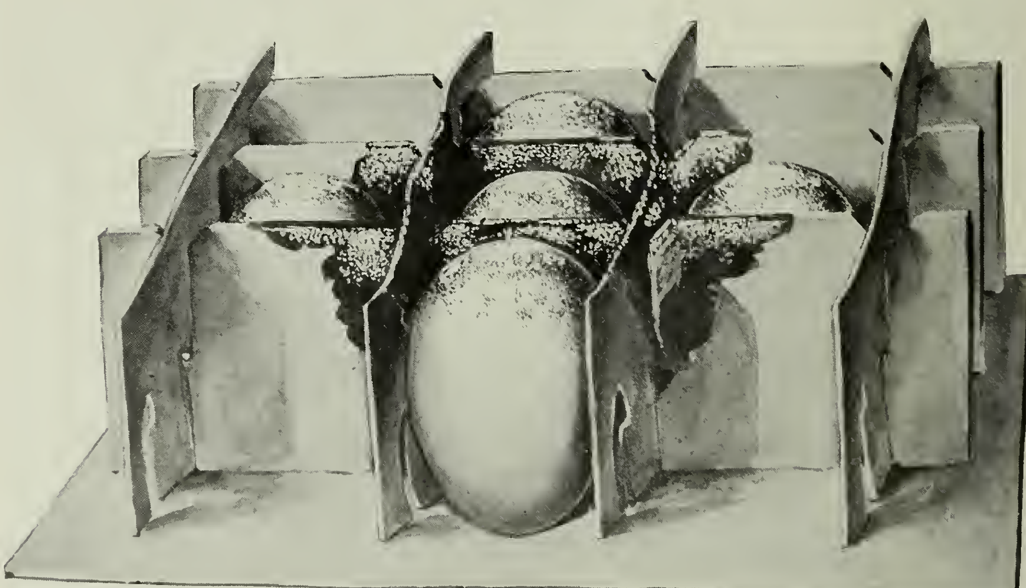
FIG. 1.—Effect of condition of shell upon preservation of fresh eggs.



COLD-STORAGE ROOM, SHOWING BRINE COILS AND STACKS OF STORAGE-PACKED EGGS. CAPACITY, 4,000 CASES, OR 1,440,000 EGGS.



Upper layer.



Lower layer.

CONTAMINATION OF NEIGHBORING EGGS BY A MOLDING LEAKER.

RELATION OF QUALITY TO PRESERVATION.

The initial quality of the eggs influences to a large extent their preservation by cold storage. Stale, weak, and hatch-spot eggs, which are only too plentiful in eggs marketed in the summer, lose heavily after a few months holding in cold storage. In the experiment cited in Table 5 and figure 2, the stale and heated eggs stored in July developed comparatively few bad eggs up to September, but from then until the end of March the loss was from 13.5 to 24 eggs per case by candling, with 9.5 to 19 additional by breaking. The number of bad eggs developing may be higher or lower than that found in this experiment, depending upon the degree of deterioration before the eggs entered storage. The most frequent types of bad eggs present in heated stock after storing are those with slightly stuck or broken-down yolks in various stages of addling. These eggs in the early stages are a form of mixed rot and are classed as such in Table 3.

TABLE 5.—*Relation of quality of clean eggs to preservation.*

Month of withdrawal.	Fresh eggs with clean, sound shells.			Stale and heated eggs with clean shells.			Stale and heated eggs with damaged shells.		
	Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.		Eggs observed.	Bad eggs per case.	
		Candling.	Breaking.		Candling.	Breaking.		Candling.	Breaking.
April	1,026	0	0.5						
May									
June									
July				977	0	0	90	0	4
August				949	8	4	104	58	3.5
September	710	0	2.5	938	6	9	106	64	20.5
October	704	1	1.5	949	2.5	4.5	111	83	32
November	695	0.5	2	901	13.5	9.5	109	135.5	33
December	709	0.5	1	954	14.5	10.5	94	175	11.5
January	694	0	2.5	960	14	14	100	147.5	18
February	715	1	2	926	24	12.5	129	232.5	19
March	717	2.5	2.5	946	23	19	96	251	15

It does not follow, however, that because many of the eggs marketed in the summer months are shrunken and heated and do not keep well in storage, the eggs as laid by the hen in the summer are not initially as good in quality as those laid in the spring. Fresh hennery eggs laid in April and July, delivered to storage within approximately 48 hours after being laid, showed a negligible loss in bad eggs, even after a long period of storage (Table 6). The bad eggs present were those showing a slight breaking down of the yolk. No eggs with green whites or crusted yolks were found. Their absence was to be expected, because the natural condition of the shell had not been disturbed through soiling, washing, or contact with damp surroundings. The good results in this report show the improvement yet to be attained in the commercial marketing of summer eggs.

TABLE 6.—*Relative keeping quality of freshly laid April and July hennery eggs.*

April hennery eggs.			July hennery eggs.		
Months in storage.	Number observed.	Bad eggs.	Months in storage.	Number observed.	Bad eggs.
7.2	351	2	6.5	275	1
11	274	2	8.5	267	2
....	....	....	10.8	241	0

After holding from four to eight months stale and heated cracked eggs stored in July showed a total of 168.5 to 266 bad eggs per case (Table 5 and fig. 2). The higher loss in these eggs, in comparison with the clean, cracked fresh eggs stored in the spring, may no doubt be explained by the development of larger numbers of molds and bacteria during the warm weather before storing.

In short, these studies show that, for successful preservation, eggs to be stored for several months should have clean, sound shells, and be fresh in quality.

COMMERCIAL GRADING FOR STORAGE.

Most of the grading of eggs for storage is done in the producing sections, although some ungraded current receipts reach the markets in the consuming centers, particularly from shippers located in the undeveloped poultry and egg sections of the country. It is generally recognized by the industry that only the best eggs should be used for storing, and that more care should be taken in the packing of eggs for storing than for direct marketing. New cases and new medium fillers (3 pounds 3 ounces per case) ordinarily are used. A very small proportion of the eggs are candled before storing, except in the summer when the production is light and the percentage stored small. The usual procedure is to sort the current receipts into various grades by clicking and inspecting the shells. From the case of current receipts the sorters take in each hand three eggs, which, by an inward movement of the index finger, they click together (Plate III). A clear ring indicates whole shells; a deadened sound signifies the presence of cracked eggs. The latter are sorted into cases by themselves, as are also the small and dirty eggs. These eggs are marketed for immediate consumption, or are broken and frozen in cans to be used by bakers as needed. Sometimes a grade called "trade eggs," sold principally in southern markets, is made from the clean, small eggs. The large eggs with clean, whole shells are used in the storage-packed eggs. Usually two grades, firsts and extra firsts, are prepared. The former must weigh at least 42 pounds to the case, and the latter 44 pounds. The making of four grades from current receipts is shown in Plate IV.

The sorting is done by either men or women, who are frequently inexperienced. Usually the work is directed by a foreman more or less skilled in egg handling and grading.

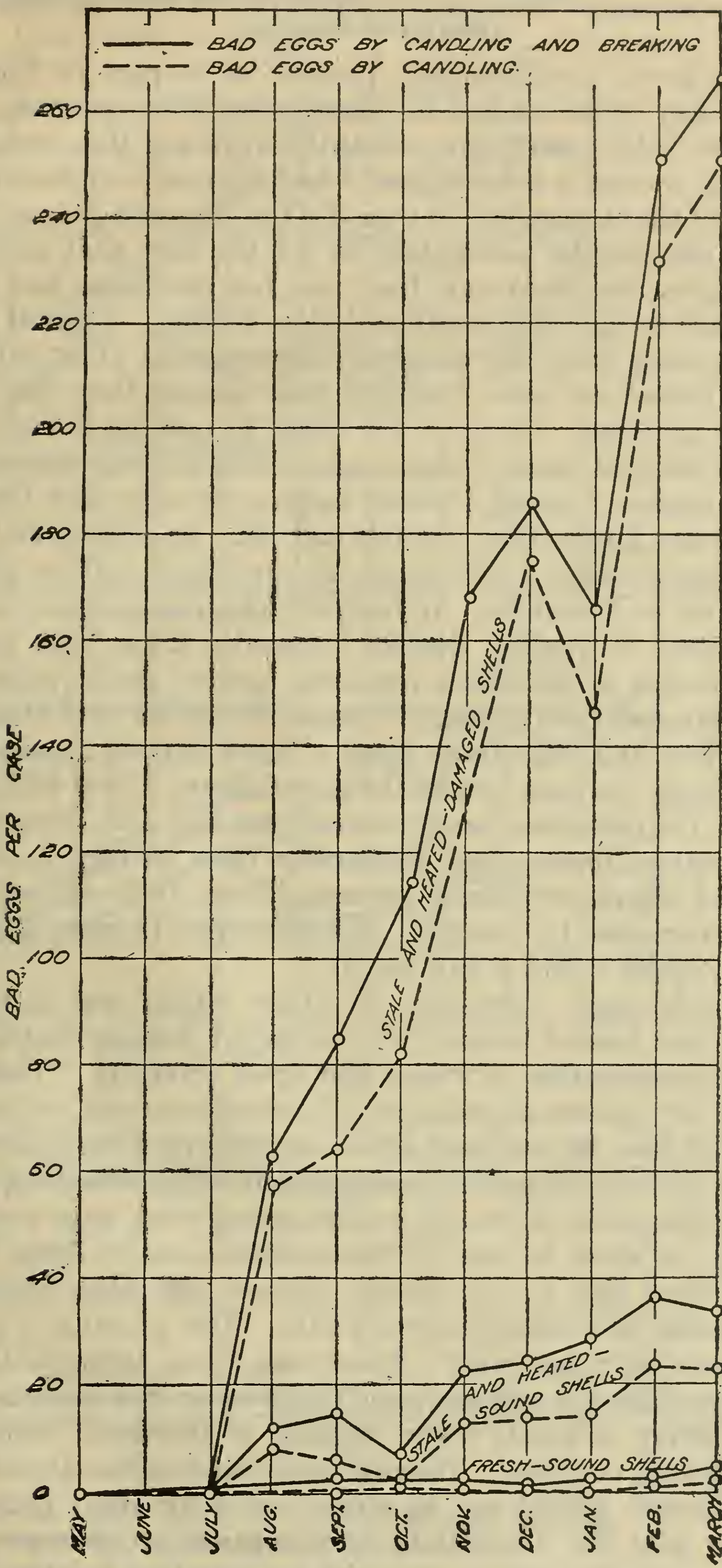


FIG. 2.—Relation of quality of clean eggs to preservation.

RELATION OF MONTH OF STORAGE TO NUMBER OF BAD EGGS IN COLD STORAGE FIRSTS AND SECONDS.

"Market firsts," commercially packed for storage in April, May, June, and July, were studied for three consecutive seasons. It may be seen from Table 7 and figure 3 that the April and May commercially packed eggs showed a low number of bad eggs more uniformly during the course of the storage period than did the June and July commercial stocks. This may be accounted for by the fact that most of the spring eggs on the market are fresh, are not shrunken, and have not been exposed to high temperatures before storing. Some of the commercial summer firsts, for example, Experiments 41782, 41941, and 41787, contained no more bad eggs after storing than did the commercial spring firsts. On the other hand, Experiments 41918, 41922, and 41945 showed heavy losses, even after a comparatively short period of storage. Indeed, it would not pay to carry such low-quality eggs in storage longer than the fall months. In commercial practice very few eggs are stored in summer, and practically all are withdrawn by November or December. In fact, in the summer when the general supply is poor in quality, dealers frequently draw from the spring stock in storage to fill orders requiring eggs of good quality.

On withdrawal from storage between November and March, commercial spring and high-grade summer firsts showed usually from 12 to 18 bad eggs per case by candling, with from 2 to 6 additional by breaking. On the other hand, summer seconds and low-grade commercial summer firsts, when withdrawn from storage between November and March, ordinarily contained from 18 to 42 bad eggs per case, as determined by candling, and from 6 to 12 more as found by breaking (Tables 7 and 8 and fig. 3).

Undergrade eggs, consisting of those which are dirty, small, shrunken, and heated, usually are marketed directly in the shell or used in the preparation of frozen and dried products. These grades of eggs are very seldom stored, except for short intervals, as the industry realizes that they do not keep well in storage for long periods. It is frequently convenient for the management of egg-breaking plants to buy large quantities of seconds in the spring when eggs are plentiful and cheap, to store for one or two months, and to open when the supply of these eggs on the market is short and when otherwise the breaking room would be practically idle. This practice is warranted only for very short intervals. There may be no appreciable increase in bad eggs during a storage period of four or five months, but the general quality is much lower because of increased staleness and higher bacterial content.[1] Because deterioration has already begun, summer seconds should not be stored, even for short periods; they should be sold for immediate consumption or promptly broken and frozen. In short, for successful preservation in storage in the shell, eggs, like other perishable products, must initially be in prime condition.

[1] Unpublished results.

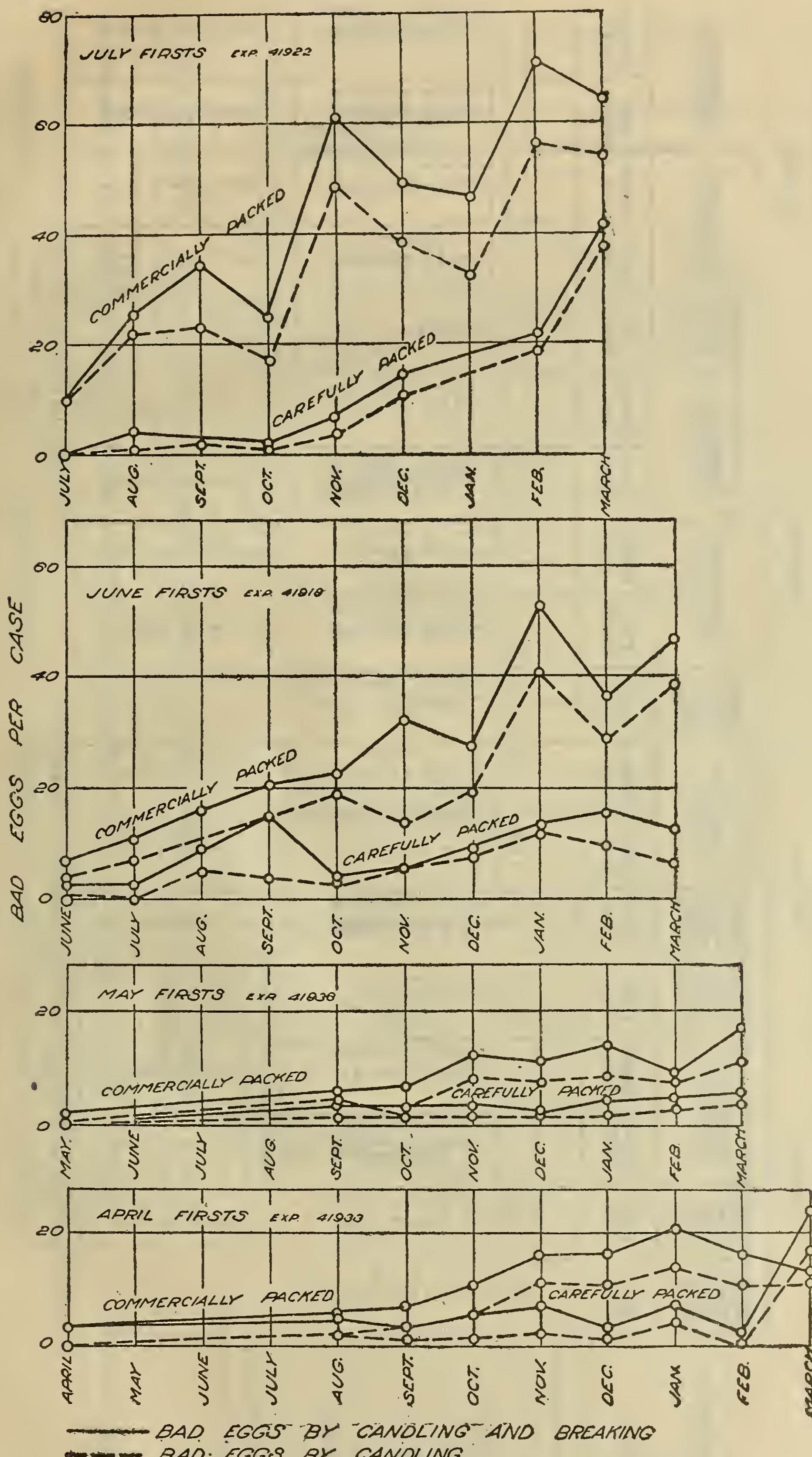


FIG. 3.—Increase in bad eggs per case in refrigerator firsts during storage.

TABLE 7.—*Increase in bad eggs per case in refrigerator firsts during storage.*

Month of withdrawal.	April firsts.				May firsts.				June firsts.					July firsts.				
	Experiment 41680 (1914).	Experiment 41896 (1915).	Experiment 41933 (1916).		Experiment 41716 (1914).	Experiment 41916 (1915).	Experiment 41936 (1916).		Experiment 41782 (1914).	Experiment 41918 (1915).		Experiment 41941 (1916).		Experiment 41787 (1914).	Experiment 41922 (1915).		Experiment 41945 (1916).	
	Candling.	Candling.	Candling.	Breaking.	Candling.	Candling.	Candling.	Breaking.	Candling.	Candling.	Breaking.	Candling.	Breaking.	Candling.	Candling.	Breaking.	Candling.	Breaking.
COMMERCIALLY PACKED:[1]																		
April	0	0.5	0.5	4.5	......	......	......	......	......	......	......	......	......	......	......	......	......	......
May	0	2.5	......	......	0.5	2	0.5	1.5	......	......	......	......	......	......	......	......	......	......
June	0.5	2.5	......	......	2	2	......	......	4	4	3.5	1.5	1	......	......	......	......	......
July	0.5	9	......	......	3	2.5	......	......	4	7.5	3	......	......	0	10	0.5	3.5	2.5
August	1	7.5	2.5	13.5	5	10	......	......	4.5	9.5	6.5	1.5	2.5	1	22	3.5	10.5	9.5
September	4	9.5	3	11.5	4	10	4	2	6	12.5	8	2	2.5	2	23.5	10.5	12.5	4.5
October	2	10.5	5.5	5	4	24	3	3.5	8	19	4.5	5	4	2	17.5	7.5	24.5	5.5
November	12.5	10.5	11.5	5	6.5	13.5	8	4	6	14	18.5	8	6	2	48.5	13	28.5	8
December	11	16.5	11.5	5	12	19.5	7	4.5	7.5	19.5	8.5	2.5	8.5	5	38.5	11	24.5	17
January	15.5	15	14	6.5	6	25	8.5	5.5	7.5	41	12	13.5	12	......	33	14.5	20.5	14
February	21	13.5	10.5	5.5	13	22.5	7	2	......	29.5	9	14	5.5	......	56.5	15	49.5	15.5
March	......	36.5	10.5	2.5	33	21.5	11	6	......	39.5	8	9.5	4.5	......	55	10.5	45.5	4.5
CAREFULLY PACKED:[2]																		
April	......	0	0	4	......	......	......	......	......	......	......	......	......	......	......	......	......	......
May	......	1	......	......	......	0	0	0.5	......	......	......	......	......	......	......	......	......	......
June	......	1	......	......	......	0	......	......	......	0	2.5	0	1	......	......	......	......	......
July	......	0	......	......	......	0	......	......	......	0	3	......	......	......	0	0	0	2.5
August	......	3	2	1	......	1	......	......	......	5	4.5	1	2	......	1	3	2	9
September	......	1	1	1	......	1	1	2.5	......	4	11	0	5	......	2	......	22	17
October	......	2	1	5	......	3	1.5	1.5	......	3	1	2	2	......	1	1	14	7
November	......	2	2	5	......	3	1.5	2	......	6	0	1	3	......	4	3	13	4
December	......	3	1	2	......	2	1	1	......	8	1	2	3	......	11	4	14	12
January	......	2	4	3	......	2	1.5	2.5	......	12	......	3	12	......	......	......	18	5
February	......	8	0	2	......	15	2.5	2	......	10	6	8	1	......	19	3	43	9
March	......	7	17	7	......	2	3	2.5	......	7	6	11	2	......	38	4	26	5

[1] Five cases examined monthly in 1914 and three monthly in 1915 and 1916.

[2] One case examined monthly.

TABLE 8.—*Increase in bad eggs per case in refrigerator seconds during storage.*

Month of withdrawal.	April dirty eggs.	May dirty eggs.	June dirty eggs.	June seconds.		June dirty eggs.		July seconds.	July dirty eggs.	July seconds.	
	Experiment 41679 (1914).	Experiment 41686 (1914).	Experiment 41778 (1914).	Experiment 41919 (1915).		Experiment 41943 (1916).		Experiment 41788 (1914).	Experiment 41805 (1914).	Experiment 41923 (1915).	
	Candling.	Candling.	Candling.	Candling.	Breaking.	Candling.	Breaking.	Candling.	Candling.	Candling.	Breaking.
COMMERCIALLY PACKED:[1]											
April	3.5										
May	3	5									
June	3	10	12	9.5	11	8.5	3				
July	3.5	12	16	10.5	9.5	17		0	0	21.5	3.5
August	6	11	23.5	12	8	17	19	7	18	48.5	18.5
September	9.5	35	29	27.5	17	42	14	4.5	19	22.5	9.5
October	11	20	22.5	28.5	9.5	25.5	16.5	8	23	26.5	13.5
November	14.5	26.5	32	26	16.5	22.5	10.5	15.5	35	44	19
December	20	24	41	38.5	14	32.5	13	11	38	58.5	7.5
January	30	32.5		37.5	13.5	59	19			56.5	14.5
February	30	28		56.5	28.5	68.5	13.5			52	17.5
March		67		54.5	20.5	74.5	7.5			52.5	20.5
CAREFULLY PACKED:[2]											
April											
May											
June				0	11	0	3				
July				2	9					0	20
August				11	7	4	13			3	
September				5	16	10	15			4	16
October				9	11	11	16			2	11
November						11	8			29	11
December				12	7	4	4			11	7
January				25		11				14	
February						18	4			16	37
March				49	8	26	13			13	8

[1] Five cases examined monthly in 1914 and three monthly in 1915.

[2] One case examined monthly.

CONDITION OF COMMERCIAL PACKAGES AS STORED.

Most warehouses require an examination of the cases of eggs for mechanical damage before permitting them to be taken to the cold-storage rooms, the thoroughness of the examination depending upon the strictness of the management. The officials of some warehouses demand that representative portions of carload lots be inspected, while others ask that each case be examined. In some cold-storage plants the examinations are made by the employees; in others, by the patrons. In the latter instance some firms exercise more care in inspection than the rulings of the warehouse require. In the warehouse where the eggs used in these investigations were stored, each patron examines his eggs and usually every case is opened. The top layers of each case are examined without being removed (Pl. V, fig. 1), or they are lifted from the case and both the upper and lower sides examined (Pl. V, fig. 2 and Pl. VI, fig. 1). When evidences of broken eggs are found in the top fillers (Pl. VI, fig. 2) each layer is inspected, and all leaking eggs discovered are replaced by eggs with whole shells in dry fillers. If no breakage is found in the top layers the remaining layers are undisturbed.

The cases of eggs under observation were inspected according to the system shown in Plate V, figure 2, and Plate VI, figure 2. These cases, then, represented the condition of commercial packages on entering storage. The eggs were next candled to determine quality and to ascertain the number of dirty, cracked, leaking, and bad eggs included with the good, clean eggs. Representative samples were also broken to further discover the quality and to find the number of bad eggs not recognized by candling, and samples of the liquid edible product were prepared for chemical analysis (Table 9, "Eggs as stored", and Tables 12 and 13).

GRADING EGGS FOR COLD STORAGE BY INSPECTING AND CLICKING THE SHELLS.

GRADING CURRENT RECEIPTS INTO STORAGE-PACKED EXTRA FIRSTS, STORAGE-PACKED FIRSTS, TRADE EGGS, AND CRACKED AND DIRTY EGGS.

FIG. 1.—TOP FILLER EXAMINED WITHOUT REMOVING EGGS UNLESS DAMAGE IS FOUND.

FIG. 2.—REMOVING TOP LAYERS AND INSPECTING UPPER AND LOWER SIDES.

INSPECTING STORAGE-PACKED EGGS. IF DAMAGE IS FOUND IN TOP FILLERS ALL THE LAYERS ARE REMOVED AND SOUND EGGS SUBSTITUTED FOR THE BROKEN EGGS.

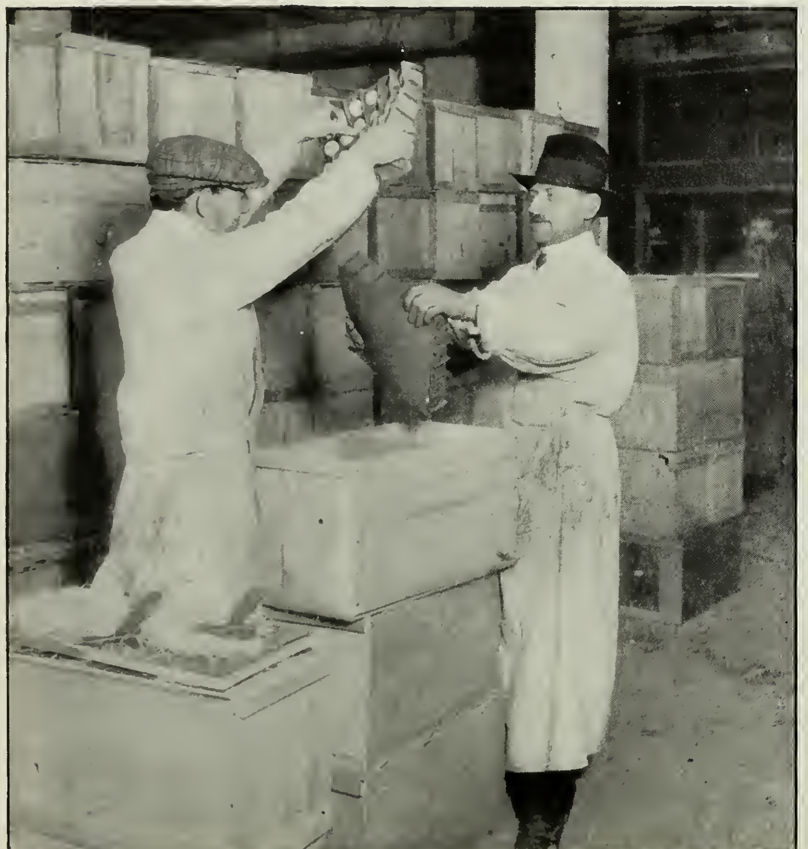


FIG. 1.—EACH WORKER WITHDRAWS A LAYER AND HOLDS THE BOTTOM IN POSITION FOR THE OTHER WORKER TO INSPECT.

FIG. 2.—LAYER OF EGGS SHOWING WET SPOTS ON FLAT, DUE TO DAMAGED EGGS.

INSPECTING CASES OF STORAGE-PACKED EGGS. IF DAMAGE IS FOUND IN TOP FILLERS ALL LAYERS ARE REMOVED AND SOUND EGGS SUBSTITUTED FOR THOSE THAT ARE BROKEN.

TABLE 9.—*Relation of care in initial sorting to bad eggs in refrigerator eggs.*

[Data given as eggs per case from eggs withdrawn from storage from November to March, inclusive.]

Experiment No.	Grade.	Cases.	Method of packing.	Eggs as stored. By candling. Good eggs. Clean.	Dirty.	Cracked.	Leaking.	Bad eggs.	Haul damage.[1] Cracked.	Leaking.	Bad eggs after storing. By candling. Clean.	Dirty.	Cracked.	Leaking.	Contaminated.	Total.	By breaking. Whole.	Damaged.	Total.	Grand total bad eggs.
41896[2]	April firsts	33	Commercial[3]	333.5	5	19	2	0.5	5.5	0.5	4	0.5	9	2	2	17.5	......	1.5	......	......
41897[2]	....do	11	Careful[3]	360	0	0	0	0	8	1	3	0	1	0	0	4	......		......	......
41933	....do	24	Commercial	312.5	27	19.5	0.5	0.5	2	0.5	2	0.5	6	1	1	10.5	4	1	5	16
41934	....do	8	Careful	360	0	0	0	0	2	0	4.5	0	0.5	0	0	5	4	0	4	9
41916	May firsts	30	Commercial	338.5	1	17	1.5	2	3	0.5	7	0	7.5	1.5	2	18	......	1	......	......
41917	....do	10	Careful	360	0	0	0	0	2.5	0.5	4.5	0	0.5	0	0	5	......		......	......
41936[4]	....do	42	Commercial	327.5	16	15	0.5	0.5	3	0.5	2.5	0.5	4	0.5	0	7.5	4	0.5	4.5	12.5
41937	....do	18	Careful	360	0	0	0	0	2.5	0	1.5	0	0	0	0	1.5	2	0	2	3.5
41918	June firsts	27	Commercial	336.5	0.5	16.5	2.5	4	3	0.5	9	0	8	2	4	23	10.5	1	11.5	38.5
41920	....do	19	Careful	360	0	0	0	0	4	0.5	8	0	0.5	0	0	8.5	3	0	3	11.5
41941	....do	23	Commercial	314	30	14.5	0	1.5	3	0	4.5	1	2	0	0	7.5	6.5	0.5	7	16
41942	....do	8	Careful	360	0	0	0	0	2	0	4.5	0	0.5	0	0	5	4	0	4	9
41922	July firsts	24	Commercial	313.5	4.5	29	3	10	3	0.5	15	0.5	16	2.5	1.5	35.5	10.5	2	12.5	58
41927	....do	8	Careful	360	0	0	0	0	3.5	0	17	0	1	0	0	18	3.5	0	3.5	21.5
41945	....do	23	Commercial	296.5	39	20	1	3.5	3.5	0.5	17	2.5	7	0.5	0.5	27.5	10.5	1	11.5	42.5
41946	....do	8	Careful	360	0	0	0	0	3.5	0	22.5	0	0	0	0	22.5	7	0	7	23.5
41919	June seconds	27	Commercial	293	35.5	20	2	9.5	2.5	0	13.5	5.5	10.5	2	1.5	33	17	1.5	18.5	61
41920	....do	7	Careful	360	0	0	0	0	3	0	27	0	2	0	0	29	16	0	16	45
41943	....do	23	Commercial	44	272	34	1.5	8.5	5	0	1	19.5	19.5	2	1	43	11	2	13	64.5
41944	....do	8	Careful	0	360	0	0	0	3.5	0	14	0	0	0	0	14	7	0	7	21
41923[4]	July seconds	24	Commercial	282	25.5	29	1.5	21.5	3.5	0.5	15	0	13	1.5	0	29.5	13.5	4.5	18	69
41927	....do	8	Careful	360	0	0	0	0	3.5	0	16.5	0	0	0	0	16.5	9	0	9	25.5

[1] From commission house to warehouse and return.
[2] Poor fillers.
[3] Three to five commercially packed cases and one carefully packed case examined monthly.
[4] One-half egg per case short.

The number of bad eggs found by candling among commercial spring firsts before storing averaged from 0.5 to 2 eggs per case, as compared with 1.5 to 10 eggs per case in the summer packed firsts. As would be expected, the initial number of bad eggs in the summer seconds was higher, averaging from 8.5 to 21.5 per case in the different lots (Table 9). The bad eggs found by candling could not have been recognized by sorting, that is, by visual inspection and clicking of shells; therefore, their presence did not reflect upon the accuracy of the initial sorting, but upon the inadequacy of the system as compared with candling. The additional bad eggs found by breaking, consisting mostly of green whites, averaged from 0.5 to 4.5 eggs per case in the spring and summer supply. The condition of these eggs, not recognizable by candling, would not be discovered in the routine marketing until opened by the consumer.

The number of cracked eggs averaged from 14.5 to 29 per case in the storage packed firsts, and from 20 to 34 per case in the summer seconds. The leakers averaged from none to 3 per case in the different lots studied, showing that the absence of damage in the top layers, as determined by commercial inspection, does not always indicate that there is none in the lower layers. The findings here corroborate the more extensive investigations made by Pennington, McAleer, and Greenlee.[1]

Some lots of storage packed firsts contained but few dirty eggs; others showed an average of 30 eggs per case. The presence of dirty eggs in commercial packages may be attributed directly to oversight or carelessness in the initial sorting of the eggs for storage.

ANALYSIS OF BAD EGGS IN COMMERCIAL FIRSTS AND SECONDS AFTER STORING.

Studies were made to determine the relative number of bad eggs developing in storage from whole, cracked, and leaking eggs present in the commercial storage stocks. These observations were based on spring and summer eggs withdrawn at monthly intervals from November until March, inclusive. Three cases of each lot were examined monthly, but, for simplicity, the results for the entire period are averaged. It was observed that most of the bad eggs developing in storage packed eggs were evident by November.

As might be expected, a large portion of the cracked eggs originally present in the commercial packages spoiled during storage (Table 9, "Bad eggs after storing," and figs. 4 and 5). Out of the average of from 15 to 19.5 cracked eggs per case present when the commercial spring firsts entered storage, from 4 to 9 bad eggs per case developed, as detected by candling, and from 0.5 to 1.5 additional per case as found by breaking. The losses were still higher in the summer packed firsts. For example, Experiment 41945 when stored contained an

[1] U. S. Dept. Agr. Bul. 664.

average of 20 cracked eggs per case, of which 8 were found to be inedible after storing. Practically all of the leaking eggs spoiled by molding.

Damaged eggs, particularly leaking eggs, in becoming moldy may contaminate neighboring eggs and cause them to spoil. When the contents of a broken egg leak out and soak into a strawboard filler, the filler usually becomes moldy, and causes eggs coming in contact with it to mold. This contamination may extend to eggs in adjoining

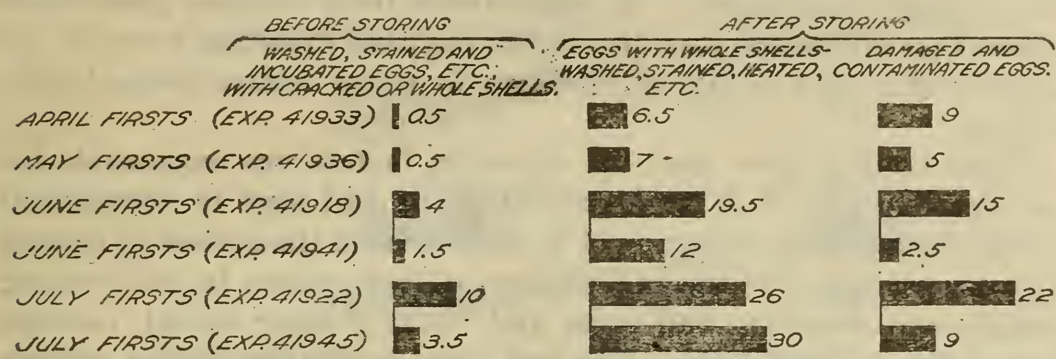


FIG. 4.—Analysis of bad eggs in refrigeration firsts, commercially packed (data given as bad eggs per case from Table 9.)

pockets or through flats to the eggs beneath. Plate II illustrates an aggravated case of the spoilage which may result from the presence of only one badly broken egg in the case. In the different lots of eggs studied, an average of from 1 to 4 eggs with sound shells per case was spoiled by leaking eggs.

Dirty eggs constituted but few of the bad eggs present in the commercially packed firsts. As found by candling, the bad eggs with dirty shells averaged from none to 2.5 eggs per case in the different lots examined.

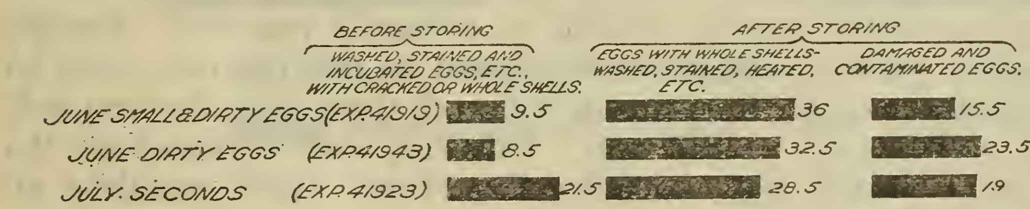


FIG. 5.—Analysis of bad eggs in refrigerator seconds, commercially packed (data given as bad eggs per case from Table 9.)

The clean eggs with sound shells constituted the majority of the eggs in the commercial cold storage firsts. In the spring stocks these eggs furnished an average of from 2 to 7 bad eggs per case, as found by candling, and an average of 4 extra, by breaking. In the summer stocks they contributed an average of 4.5 to 17 bad eggs per case by candling, and 6.5 to 10.5 additional by breaking. The inedible eggs in the clean summer seconds with sound shells, as found by candling and opening, were practically the same in number as the poorer grade of summer firsts. A large proportion of the bad eggs in the

spring firsts with whole shells may be attributed to the presence of eggs which at some time previous to storage had had wet shells, because of washing the eggs or for some other reason. If the dirt is left on the shells the eggs can be graded accordingly, but if washed it is not always possible to differentiate between them, with the result that washed eggs are frequently graded as firsts. Washed eggs do not keep as well as dirty eggs. Attempts, therefore, to improve the appearance of dirty eggs by washing is a practice which can not be too strongly condemned. In eggs stored from summer production there is an additional loss due to the physical breaking down of the egg contents as a result of exposure to warm temperatures before storing.

These studies show that the following factors are responsible for the development of a large percentage of bad eggs in commercial spring firsts during storage: (1) Inaccuracies in the system of sorting eggs for storage; (2) the inadequacy of that system in determining quality and detecting bad eggs; and (3) to a lesser extent, damage during the railroad haul. The bad eggs developing during storage in the summer stocks are due to these factors, combined with a lower initial quality.

CAREFULLY PREPARED PACKAGES.

In order to determine the relation between care in initial grading and the number of bad eggs developing during storage, packages containing as far as possible only good eggs with clean whole shells were prepared from each lot of commercially packed eggs studied during the last two seasons of the investigation. To determine quality and to eliminate bad eggs, the eggs were selected by candling instead of by simply inspecting and clicking the shells.

Candling is a more accurate method for the detection of cracked eggs than is the clicking of shells, as ordinarily practiced. Enough carefully graded packages were prepared so that one case could be withdrawn monthly from storage with each three cases of corresponding commercially packed eggs. Following such a procedure, the carefully packed eggs, excluding Experiment 41897, contained an average of three cracked eggs per case after carting from the commission house to the cold storage warehouse and return. Of this number from one to two of the cracked eggs may be accounted for by handling error in putting up the eggs for storage, and the balance by damage during cartage. The number of cracked eggs in Experiment 41897 was unusually high, largely because of the use of a very poor grade of filler, so that more damage than usual was incurred during cartage.

Table 9 and figures 6 and 7 show that the number of inedible eggs present after storing was reduced in the carefully packed, as compared with the commercial cases. In the April and May refrigerator

firsts there was an average of 13.5 inedible eggs per case found by candling in the commercially packed eggs, as compared with 4 in those carefully packed. These figures are the averages of the results of monthly observations made from November to March. Figuring the value of eggs when stored in the spring of 1917 as 35.6[1] cents per dozen, and charging 3 cents a dozen to cover insurance, interest, and carrying cost, there was an average money loss in bad eggs in the commercially packed eggs of 43.5 cents, as compared with 13 cents per case in those

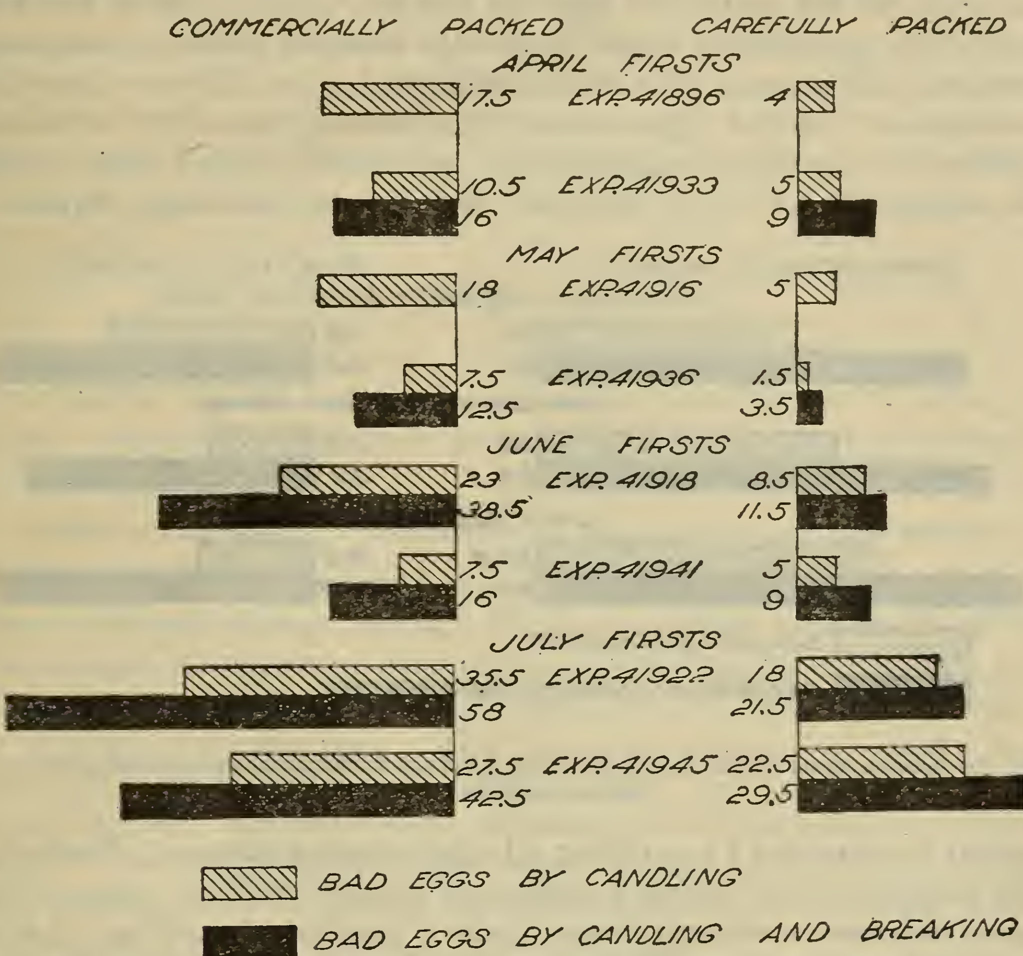


FIG. 6.—Relation of care in initial sorting to number of bad eggs in refrigerator firsts (data given as bad eggs per case from Table 9).

carefully packed. An average of 11 cracked eggs, which were still good by candling, was found in the case of the commercially packed eggs. These, however, on account of their impaired shells, would bring one-third less on the markets than their companion eggs with good shells, making a further additional loss of 12 cents per case. The total loss, then, in the commercial stocks averages 55.5 cents per case, as compared with 13 cents in the carefully packed eggs. It costs about 5 cents more per case to grade by candling than by sorting. Even

[1] U. S. Dept. Agr., Bureau of Markets Report of Mar. 11, 1918.

with this added expense there was a saving of 37.5 cents per case in favor of the carefully packed eggs which amounts to $140 per carload of 400 cases in spring stocks stored until after November.

In the summer commercial firsts and seconds careful packing did much to reduce the number of bad eggs developing during storage, but it did not offset the losses due to the lower initial quality of the entering material (Table 9 and fig. 7).

It is believed with a little attention given to the checking of the accuracy of the sorting of eggs for storage, the number of cracked and dirty eggs missed could be greatly lessened without materially reducing the amount of work accomplished. In addition, since the detection of cracked eggs depends upon hearing distinctly the sound emitted on tapping the eggs together, noises in the work room should be eliminated as far as possible. Far greater efficiency, however,

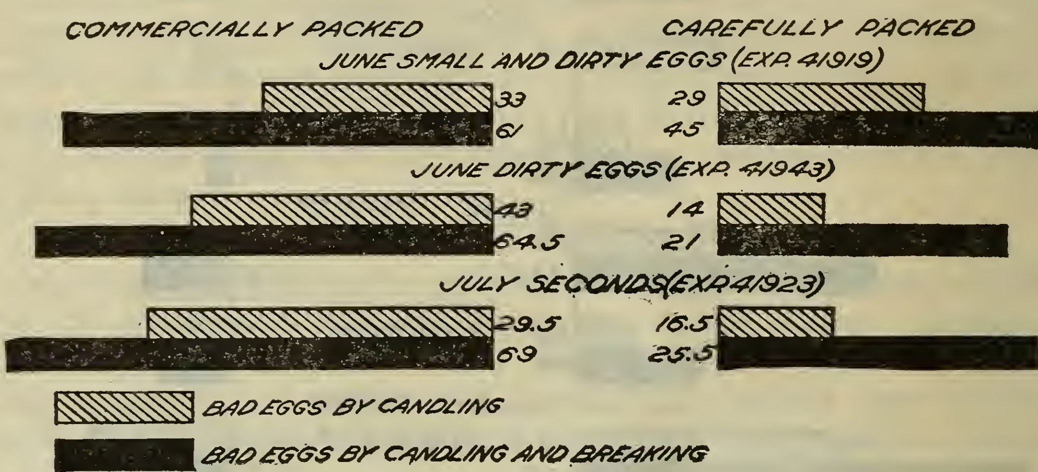


FIG. 7.—Relation of care in initial sorting to number of bad eggs in refrigerator seconds (data given as bad eggs per case from Table 9).

would be obtained by candling all eggs entering storage. Realizing the importance of having a uniformly graded product, some of the more progressive western houses make a practice of candling all eggs stored, at the same time enforcing a checking system [1] to see that the work is accurately done. This is a big step forward, for by candling the cracked eggs can be more accurately eliminated, and low quality and bad eggs may be detected and discarded. Under such a system the graders become so skilled that their work is as accurate as that of the carefully packed stocks of this investigation.

Such eggs, being practically free from mold after several months in storage, are an advertisement to the firm selling them, and in practice it has been found that their more uniform quality has secured for them special outlets with higher prices. According to the present system of marketing, storage packed eggs may pass through several hands before they are finally consumed, with the

[1] U. S. Dept. Agr. Bul. 702.

result that the original shipper seldom sees the condition of his goods when they are withdrawn from storage. For example, the packer in the producing section may sell to a commission man in the East, who in turn may sell to another dealer. Upon withdrawal from storage the eggs may go into another buyer's hands before they are finally graded for the retail market. In addition to buying according to shrinkage before the candle and weight, dealers in storage packed eggs should demand that the cases be practically free from cracked eggs. This factor has received too little attention in the past, taking into consideration the fact that the average of 19 cracked eggs per case as the eggs leave the shipper's hand frequently furnishes half of the bad eggs developing during storage. In the final analysis, the original packer must bear the burden of expense of the stale, dirty, cracked, leaking, and bad eggs included in the storage grade, for, in order to play safe, buyers must pay a lower price for the whole package than they would if sure of receiving cases containing only large, clean, fresh eggs with whole shells. If there is no direct market for the cracked, dirty, shrunken, and leaking eggs in the shell, their initial quality can be conserved by breaking and freezing in cans. Ordinarily there is a good market for frozen egg products of high quality.

SHRINKAGE OF EGGS AND ABSORPTION OF MOISTURE BY CASE AND FILLERS.

The changes in weight of eggs, case, and fillers were studied in three different storage rooms. All the weighings were made in the room where the eggs were held, because it was found that the cases and fillers frequently gained in weight if removed to a higher temperature. A sensitive scale was used. First the gross weight was found; then the eggs were transferred to a second case, and the fillers and the case weighed. The net weight of the eggs was determined by difference. After weighing, the eggs were returned to the original cases and fillers, so that the periodical weighings during the storage period were made on the same cases, fillers, and eggs.

There was an almost regular decrease in the net weight of the eggs during the course of the storage period, amounting to an average of 4.48 ounces per case per month for eggs stored in Room 1, and 3.46 ounces per month for eggs stored in Rooms 2 and 3. In Room 1 the decrease in the gross weight of a case of eggs weighing initially 56.84 pounds gross and 45.80 pounds net was 25.29 ounces and 38.20 ounces, respectively, during a storage period of 9.2 months. In Room 2 a case of eggs weighing 57.33 pounds gross and 45.01 pounds net at the beginning of the season lost 12.73 ounces gross and 26.14 ounces net after 9 months in storage. These typical results show, then, that attempts to determine shrinkage of eggs by finding changes in weight of the total package alone, a procedure frequently followed commercially, give misleading figures (Table 10 and fig. 8).

TABLE 10.—*Shrinkage of eggs and rate of absorption of moisture by case and fillers (case lots).*

COLD STORAGE ROOM 1.

Initial weight and time in storage.	Shrinkage (loss in weight).												Absorption of moisture (gain in weight).											
	Total package.						Eggs.						Fillers and flats.						Case.					
	Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.	
Initial weight (pounds).	56.84		55.37		54.50		45.80		43.53		43.09		3.78		3.68		3.61		7.27		8.16		7.74	
	Oz.	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*
1 month, 5 days	3.00	0.33	4.09	0.46	1.76	0.20	7.37	1.00	5.89	0.85	5.22	0.76	2.40	3.97	1.87	3.17	1.76	3.01	2.00	1.70	−0.07	−0.05	1.69	1.36
2 months, 3 days	5.19	0.57	8.40	0.93	7.94	0.91	10.01	1.36	9.81	1.40	11.14	1.61	2.61	4.32	1.59	2.70	1.83	3.13	2.22	1.91	0.18	0.13	1.38	1.11
3 months, 6 days	9 88	1.09	10.93	1.23	12.35	1.42	16.26	2.21	13.05	1.87	15.66	2.27	3.14	5.19	2.01	3.41	1.94	3.31	3.17	2.73	0.11	0.08	1.38	1.11
4 months, 8 days	14.14	1.56	16.59	1.87	15.17	1.74	21.34	2.91	19.08	2.70	20.42	2.96	3.74	6.18	2.29	3.89	2.58	4.40	3.46	2.97	0.21	0.16	2.68	2.16
5 months, 6 days	14.71	1.62	18.10	2.04	18.59	2.13	24.55	3.35	21.98	3.15	23.84	3.46	6.21	10.26	2.82	4.79	2.58	4.40	3.63	3.12	1.05	0.81	2.68	2.16
6 months, 13 days	17.35	1.91	24.12	2.72	20.46	2.35	28.15	3.84	27.76	3.98	27.48	3.98	6.53	10.79	2.82	4.79	3.32	5.66	4.27	3.67	0.81	0.62	3.70	2.99
7 months, 13 days	19.40	2.13	25.15	2.84	23.91	2.74	31.36	4.28	30.55	4.38	31.04	4.50	7.27	12.01	3.35	5.67	3.53	6.02	4.69	4.03	2.04	1.57	3.95	3.19
8 months, 8 days	21.76	2.39	26.28	2.96	25.93	2.97	34.53	4.71	32.73	4.70	33.72	4.88	7.44	12.31	3.88	6.59	3.60	6.14	5.33	4.58	2.58	1.98	4.20	3.39
9 months, 7 days	25.29	2.78	28.29	3.19	28.64	3.28	38.20	5.21	35.52	5.10	37.35	5.42	7.44	12.31	4.13	7.01	3.99	6.81	5.47	4.70	3.10	2.39	4.73	3.81
9 months, 25 days	28.29	3.11	31.39	3.54	31.04	3.56	41.23	5.62	38.38	5.58	38.87	5.64	7.44	12.31	4.06	6.89	3.81	6.51	5.47	4.70	2.93	2.25	4.02	3.24
Average monthly loss	......	......	......	......	......	......	4.70	0.64	4.27	0.61	4.46	0.65	......	......	......	......	......	......	......	......	......	......	......	......

COLD STORAGE ROOM 2.

Initial weight and time in storage.	Shrinkage (loss in weight).												Absorption of moisture (gain in weight).											
	Total package.						Eggs.						Fillers and flats.						Case.					
	Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.		Case 1.		Case 2.		Case 3.	
Initial weight (pounds).	58.29		56.04		57.33		45.37		44.37		45.01		3.70		3.71		3.71		9.22		7.98		7.98	
	Oz.	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*
23 days	+1.58	+0.17	+4.23	+0.47	+0.50	+0.04	4.40	0.61	2.29	0.32	5.22	0.73	2.93	4.94	2.75	4.75	2.36	3.97	3.07	2.07	3.49	2.73	2.86	2.07
1 month, 21 days	+0.88	+0.10	+0.35	+0.04	+0.84	+0.09	7.55	1.04	8.08	1.14	7.44	1.03	4.23	7.15	3.77	6.36	3.63	6.11	4.20	2.84	4.37	3.42	4.16	3.01
2 months, 24 days	+0.53	+0.06	0.02	0.02	1.20	0.13	10.19	1.40	11.39	1.61	11.75	1.63	5.36	8.91	4.87	8.20	4.62	7.77	5.01	3.39	6.07	4.75	5.43	3.93
3 months, 25 days	0.35	0.04	3.17	0.35	3.21	0.35	12.52	1.77	14.57	2.06	14.43	2.00	5.75	9.72	4.87	8.20	4.83	8.07	6.42	4.35	6.24	4.89	5.89	4.26
5 months, 3 days	1.80	0.19	3.52	0.39	4.44	0.48	14.50	1.99	16.26	2.30	17.21	2.39	6.03	10.20	5.47	9.21	5.64	9.50	6.67	4.51	6.98	5.46	6.63	4.79
6 months	3.52	0.38	5.47	0.60	4.97	0.54	16.83	2.32	19.51	2.76	18.48	2.57	6.28	10.61	5.89	9.74	5.82	9.79	7.02	4.75	7.69	6.02	7.02	5.07
7 months, 6 days	5.64	0.61	7.02	0.78	7.94	0.87	17.53	2.41	20.71	2.93	20.53	2.85	4.69	7.93	5.75	9.69	5.82	9.79	7.20	4.88	7.55	5.90	6.49	4.69
8 months, 6 days	7.94	0.85	10.40	1.16	11.25	1.22	22.05	3.03	23.77	3.36	25.00	3.47	6.53	11.03	5.93	9.98	6.10	10.26	7.58	5.14	7.69	6.02	6.35	4.59
9 months, 1 day	7.76	0.83	16.40	1.29	12.73	1.35	22.92	3.16	26.17	3.70	26.14	3.63	6.81	11.50	6.46	10.87	6.17	10.37	7.30	4.95	7.80	6.11	6.70	4.84
9 months, 29 days	12.52	1.34	14.46	1.61	16.72	1.82	25.08	3.45	29.03	4.10	29.88	4.15	6.24	10.55	6.56	11.05	5.93	9.97	6.60	4.47	7.73	6.03	6.70	4.84
10 months, 17 days	14.64	1.57	19.15	2.13	20.60	2.24	27.69	3.81	32.10	4.53	32.59	4.53	6.53	11.03	5.93	9.98	5.47	9.20	6.53	4.42	6.74	5.21	6.00	4.33
Average monthly loss	......	......	......	......	......	......	2.98	0.41	3.37	0.48	3.37	0.47	......	......	......	......	......	......	......	......	......	......	......	......

COLD STORAGE ROOM 3.

Initial weight (pounds)	57.56		57.63				45.73		45.77															
	Oz.	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*	*Oz.*	*P.ct.*
3 months, 29 days	10.00	1.08	13.93	1.51			15.52	2.12	16.33	2.23														
5 months, 16 days	16.01	1.74	17.57	1.91			22.29	3.04	21.98	3.00														
6 months, 21 days	17.04	1.85	19.65	2.13			24.48	3.34	24.80	3.39														
7 months, 13 days			19.65	2.13					26.95	3.68														
8 months, 17 days			20.32	2.20					29.78	4.07														
9 months, 17 days			19.75	2.14					31.53	4.30														
10 months, 15 days			19.01	2.06					32.94	4.50														
Average monthly loss							3.92	0.54	3.64	0.50														

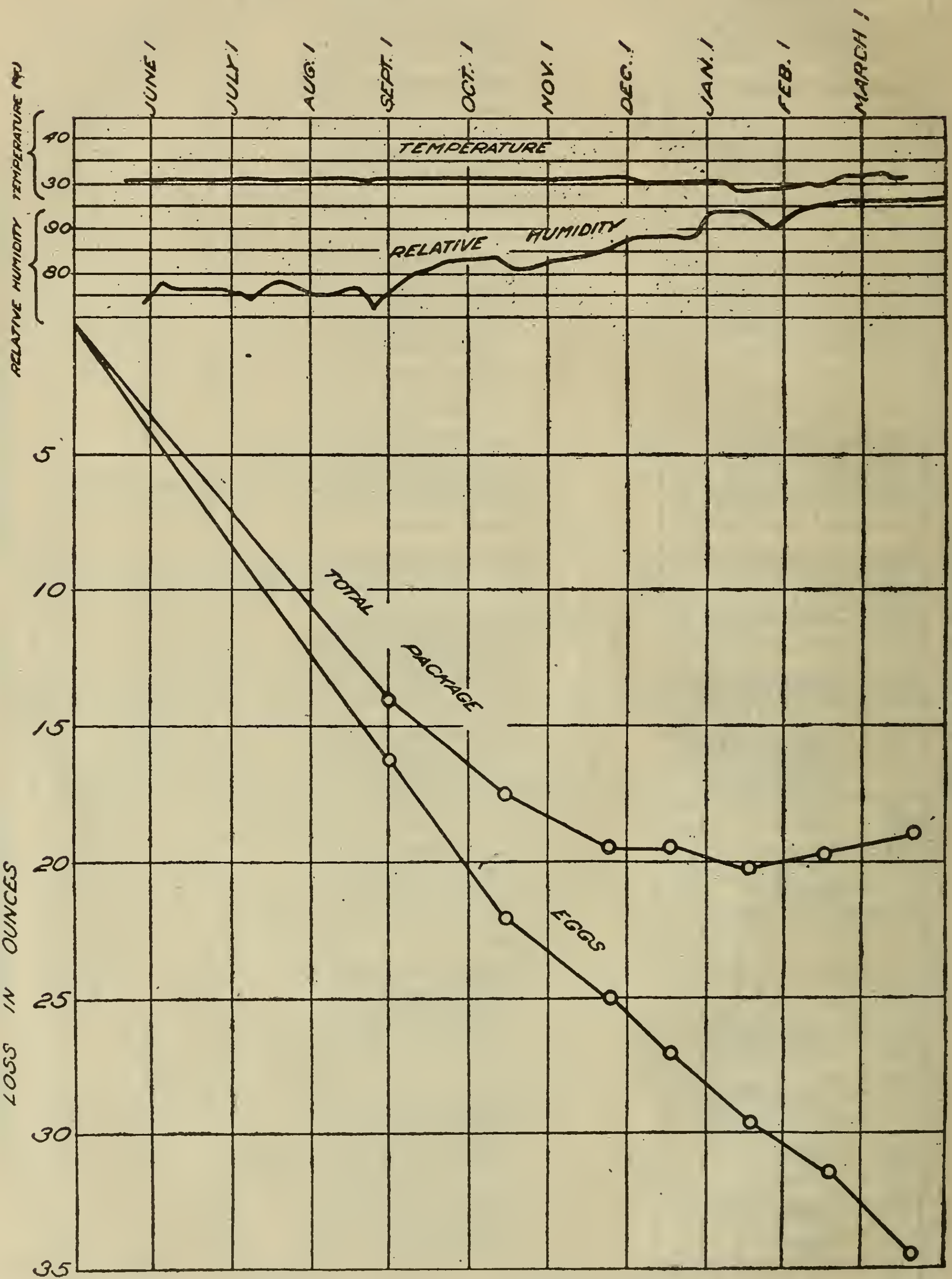


FIG. 8.—Temperature, relative humidity, and amount of shrinkage of eggs in a case of 30-dozen capacity in Cold Storage Room 3 (data from Tables 10 and 11).

The amount of moisture absorbed by the fillers and case varied in different rooms and for different cases in the same room during the storage period. Probably most of the moisture absorbed is from the water evaporating from the eggs. Cases exposed to drafts from the outside, as through the opening of doors, would condense moisture from the incoming air, but under ordinary conditions the moisture coming from this source would be small in quantity compared with that derived from the eggs. Most of the moisture was taken up by the case and fillers during the first four or five months, and from this time on the weights usually showed a slight gain or remained practically stationary. In Room 1 fillers having an initial weight of 3.61 and 3.68 pounds gained 3.99 and 4.13 ounces, respectively, after 9.2 months in storage; and in Room 2 of two sets of fillers, each weighing 3.7 pounds at the beginning, one gained 6.17 and the other 6.81 ounces in 9 months. In Room 1 cases weighing 7.74 and 8.16 pounds at the outset absorbed 4.73 and 3.10 ounces, respectively, of moisture in 9.2 months; and in Room 2 of two cases each weighing 7.98 pounds, one gained 6.70 ounces and the other 7.80 ounces of moisture during practically the same period of time (Table 10 and fig. 8).

The temperature of the three rooms in which these observations were made was quite uniform throughout the storage period. For example, in Room 3 the fluctuations in temperature were rarely more than 30° to 33° F., except during the severe winter, when the thermometer dropped to 28° F. and occasionally to 26° F. for a few hours. During most of the season the average temperature was 31° F. (Table 11 and fig. 8).

TABLE 11.—*Average relative humidity and average temperature of Cold Storage Room 3.*

Week ending.	Average relative humidity.	Average temperature.	Week ending.	Average relative humidity.	Average temperature.
1917.	*Per cent.*	°*F.*	1917.	*Per cent.*	°*F.*
May 28	74	31	Nov. 5	83	31
June 4	78	31	Nov. 12	84	31
June 11	76	31	Nov. 19	85	31
June 18	76	31	Nov. 26	87	31
June 25	76	31	Dec. 2	88	31
July 2	75	31	Dec. 9	88	31
July 8	74	31	Dec. 17	88	30
July 16	78	31	Dec. 24	88	30
July 23	78	31	Dec. 31	89	30
July 30	76	31	1918.		
Aug. 5	75	31	Jan. 7	89	30
Aug. 17	77	31	Jan. 14	89	28
Aug. 23	72	31	Jan. 21	87.5	29
Aug. 27	73	30	Jan. 28	80	29
Sept. 4	77	31	Feb. 4	89	30
Sept. 10	80	31	Feb. 11	90	29
Sept. 17	82	31	Feb. 18	90	31
Sept. 24	83	31	Feb. 25	91	32
Oct. 1	83	31	Mar. 4	91	32
Oct. 8	84	31	Mar. 11	91	31
Oct. 16	82	31	Mar. 18	91	31
Oct. 22	81	31	Mar. 25	91	....
Oct. 29	82	31	Apr. 1	91	....

Table 11 and figure 8 give the average percentage relative humidities [1] by weeks in Room 3. The humidity from the beginning of the season up to September varied from 72 to 77 per cent, and from that time until the end of the season gradually increased to a maximum of 91 per cent. The cause of the rise in relative humidity in this room may be attributed to several factors: (1) Beginning with September the doors were opened frequently on account of the removal of eggs from cold storage, thus allowing an inrush of air frequently laden with moisture; (2) during the early fall months the cases and fillers had become saturated with moisture for the temperatures at which they were held, so that they did not continue to assist materially in the removal of moisture from the air; (3) by this time the brine pipes had become heavily frosted because of the condensation of moisture from the air, which rendered them less efficient both as absorbers of heat and as condensers of moisture; (4) after the warm weather of the summer had passed, less brine was circulated through the pipes, thereby reducing their efficiency as condensation agents; (5) with the advance of the season the number of cases decreased, so that there was more air in the room to carry moisture and less surface exposed for condensation and absorption. In this room, as well as in the other two rooms in which observations were made on the shrinkage of eggs, calcium chlorid was used as a drying agent. All three rooms were chilled by brine pipes on the walls.

PHYSICAL AND CHEMICAL CHANGES IN EGGS DURING STORAGE.

During the commercial holding of eggs in cold storage the air space increases in size because of the evaporation of moisture; the white becomes thinner and eventually loses its opalescence. After six or seven months the white usually develops a yellow tinge, which deepens with the length of the storage period. The clouded appearance of the white is especially noticeable when eggs are separated in large quantities, as is done in a commercial egg-breaking room. The slightly yellow color does not destroy the beating quality of the white nor the porcelain white color of the resulting froth. The yolk membrane weakens slowly, but, if the eggs are fresh on storing, most of them can be separated, even after storage for 11 months. The separation, however, is usually not as easy as in the earlier part of

[1] The determinations of relative humidities were made according to a sulphuric acid vapor pressure method by N. Hendrickson and H. C. Woodward, which, in brief, was as follows: Two gram samples of sulphuric acid of concentrations varying from 15 to 35 per cent were allowed to come to equilibrium in the storage rooms in low, wide-mouth weighing bottles. The bottles were then covered, allowed to come to room temperature, and then weighed. The percentage of the sulphuric acid in equilibrium was calculated from the original concentration. The vapor pressure corresponding to the concentration of the sulphuric acid in equilibrium divided by the vapor pressure of saturated water vapor at 32° F. equals the percentage of the relative humidity of the air of the cold-storage room. The usual method of determining the relative humidity by a sling pschychrometer was not used, as it is not accurate at 32° F. and below, because of the freezing of the water on the wet bulb.

the storage period. If the physical condition of the egg is weakened through being stale, or heated, or both, separation is difficult after being held in storage for only a few months.

Accompanying the evaporation of moisture from the egg, Greenlee [1] found that there was a transfer of moisture from the white to the yolk by osmosis. For example, samples of whites and yolks, showing 87.42 per cent and 49.15 per cent moisture, respectively, after holding in storage for 41 days, contained 85.35 per cent and 50.60 per cent, respectively, at the end of 266 days in storage.

[1] U. S. Dept. Agr., Bur. Chem. Cir. 83.

TABLE 12.—*Increase in ammoniacal nitrogen in refrigerator firsts during storage.*

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	April firsts.						May firsts.					
	Experiment 41896.			Experiment 41933.			Experiment 41916.			Experiment 41936.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			Per cent.			Per cent.			Per cent.
April	Initial	48	0.0018	Initial	1,026	0.0019						
May	1 month 4 days	48	.0020				Initial	60	0.0021	Initial	1,047	0.0020
June	2 months 2 days	60	.0024				27 days	60	.0025			
July	3 months 8 days	60	.0022				2 months 3 days	60	.0023			
August	4 months 3 days	72	.0025	3 months 18 days	1,025	0.0023	2 months 28 days	72	.0028			
September	5 months 6 days	72	.0024	4 months 23 days	997	.0025	4 months 1 day	72	.0028	3 months 28 days	1,023	0.0025
October	6 months 5 days	72	.0027	5 months 21 days	1,019	.0026	5 months	72	.0026	4 months 26 days	1,015	.0024
November	7 months 4 days	72	.0028	6 months 17 days	995		5 months 29 days	72	.0033	5 months 22 days	1,014	.0028
December	8 months 2 days	72	.0030	7 months 25 days	981	0.0025	6 months 27 days	72	.0029	7 months	995	.0026
January	9 months 8 days	994	.0028	8 months 27 days	1,000	.0030	8 months 2 days	72	.0034	7 months 28 days	1,002	.0028
February	10 months 4 days	986	.0030	9 months 19 days	987	.0031	9 months 1 day	972	.0032	8 months 25 days	997	.0030
March	11 months 1 day	910	.0030	10 months 26 days	1,021	.0031	9 months 26 days	992	.0035	10 months 1 day	995	.0030

EGGS WITH CRACKED SHELLS.

Month of withdrawal.	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
April	Initial	64	0.0012	Initial		0.0018						
May							Initial	96	0.0014	Initial	30	0.0018
June	2 months 3 days	66	0.0012				29 days	58	.0011			
July	3 months 9 days	82	.0030				2 months 4 days	62	.0029			
August	4 months 4 days	82	.0027	3 months 18 days	48	0.0025	2 months 29 days	59	.0029			
September	5 months 7 days	40	.0026	4 months 24 days	75	.0023	4 months 2 days	61	.0028	3 months 29 days	44	.0025
October	6 months 6 days	46	.0026	5 months 21 days	44	.0028	5 months 1 day	52	.0030	4 months 26 days	59	.0025
November	7 months 5 days	71	.0026	6 months 19 days	51	.0025	6 months	39	.0034	5 months 24 days	44	.0029
December	8 months 3 days	62	.0030	7 months 25 days	65	.0031	6 months 28 days	51	.0030	7 months	57	.0025
January	9 months 8 days	41	.0028	8 months 29 days	38	.0038	8 months 3 days	33	.0031	8 months 1 day	46	.0028
February	10 months 5 days	54	.0031	9 months 22 days	61	.0032	9 months	41	.0035	8 months 27 days	56	.0032
March	11 months 2 days	61	.0040	10 months 26 days	27	.0030	9 months 27 days	24		10 months 1 day	42	.0029

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	June firsts.						July firsts.					
	Experiment 41918.			Experiment 41941.			Experiment 41922.			Experiment 41945.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			*Per cent.*			*Per cent.*			*Per cent.*
April												
May												
June	Initial	1,008	0.0026	Initial	1,024	0.0020						
July	1 month 4 days	977	.0027				Initial	903	0.0020	Initial	1,011	0.0022
August	2 months	1,000	.0024	1 month 27 days	1,034	0.0020	29 days	927	.0028	1 month 4 days	961	.0023
September	3 months 7 days	1,004	.0021	3 months 3 days	972	.0022	2 months 4 days	922	.0026	2 months 9 days	976	.0026
October	4 months 2 days	978	.0028	4 months	1,012	.0023	3 months	942	.0038	3 months 7 days	939	.0027
November	5 months 1 day	989	.0032	4 months 27 days	1,014	.0026	3 months 29 days	867	.0028	4 months 4 days	936	.0028
December	5 months 29 days	994	.0032	6 months 8 days	1,025	.0027	4 months 27 days	916	.0034	5 months 15 days	927	.0026
January	7 months 4 days	917	.0030	7 months 6 days	958	.0027	6 months 2 days	922	.0030	6 months 13 days	968	.0028
February	8 months 3 days	963	.0035	7 months 29 days	1,011	.0028	7 months 1 day	864	.0037	7 months 8 days	905	.0035
March	8 months 29 days	944	.0040	9 months 25 days	1,025	.0030	7 months 28 days	886	.0037	8 months 12 days	914	.0031

EGGS WITH CRACKED SHELLS.

Month of withdrawal.	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
April												
May												
June	Initial	48	0.0010	Initial	50	0.0018						
July	1 month 4 days	80	.0022				Initial	117	0.0014	Initial	87	0.0021
August	2 months	52	.0028	1 month 27 days	42	0.0020	28 days	87	.0029	1 month 4 days	87	.0024
September	3 months 4 days	39	.0028	3 months 3 days	102	.0026	2 months 2 days	87	.0024	2 months 10 days	67	.0024
October	4 months 2 days	45	.0029	4 months	53	.0026				3 months 7 days	68	.0028
November	5 months 1 day	49	.0030	4 months 28 days	41	.0028	3 months 28 days	68	0.0024	4 months 5 days	58	.0027
December	5 months 29 days	27	.0030	6 months 8 days	47	.0025	4 months 27 days	48	.0031	5 months 15 days	30	.0028
January	7 months 4 days	40	.0029	7 months 5 days	30	.0028	6 months 1 day	59	.0027			
February	8 months 5 days	29	.0037	8 months 1 day	27	.0030	7 months 2 days	46	.0032	7 months 18 days	27	.0041
March	8 months 28 days	18	.0040	9 months 5 days	27	.0031	7 months 28 days	28	.0045	8 months 12 days	28	.0034

TABLE 13.—*Increase in ammoniacal nitrogen in refrigerator seconds during storage.*

EGGS WITH WHOLE SHELLS.

Month of withdrawal.	June seconds.			June dirty eggs.			July seconds.		
	Experiment 41919.			Experiment 41943.			Experiment 41923.		
	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
			Per cent.			*Per cent.*			*Per cent.*
June	Initial	948	0.0011	Initial	958	0.0022			
July	29 days	992	.0026				Initial	900	0.0025
August	1 month 26 days	989	.0022	1 month 27 days	898	.0021	21 days	848	.0023
September	3 months 2 days	951	.0024	3 months 2 days	994	.0025	1 month 26 days	936	.0032
October	3 months 27 days	926	.0024	4 months	928	.0025	2 months 22 days	897	.0032
November	4 months 27 days	951	.0026	4 months 26 days	933	.0030	3 months 21 days	866	.0033
December	5 months 25 days	913	.0028	6 months 8 days	910	.0027	4 months 18 days	855	.0034
January	6 months 29 days	934	.0026	7 months 6 days	838	.0032	5 months 24 days	864	.0038
February	7 months 29 days	862	.0027	8 months	818	.0031	6 months 24 days	865	.0035
March	8 months 25 days	894	.0035	9 months 5 days	808	.0034	7 months 20 days	870	.0039

EGGS WITH CRACKED SHELLS.

Month of withdrawal.	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).	Time in storage.	Eggs in sample.	Ammoniacal nitrogen (wet basis).
June	Initial	75	0.0016	Initial	133	0.0022			
July	29 days	56	.0025				Initial	117	0.0018
August	1 month 26 days	54	.0026	1 month 27 days	131	.0021	21 days	87	.0030
September	2 months 29 days	46	.0029	3 months 3 days	54	.0023	1 month 25 days	76	.0032
October	3 months 27 days	61	.0030	4 months	75	.0026	2 months 22 days	104	
November	4 months 26 days	51	.0029	4 months 28 days	64	.0025	3 months 20 days	82	.0031
December	5 months 25 days	52	.0028	6 months 8 days	72	.0032	4 months 19 days	49	.0030
January	6 months 29 days	33	.0029	7 months 5 days	65	.0030	5 months 23 days	47	.0040
February	8 months	47	.0029	8 months	56	.0032	6 months 24 days	59	.0039
March	8 months 24 days	23	.0039	9 months 5 days	48	.0033			

The amount of ammoniacal nitrogen[1] in samples of April and May storage eggs graded as edible by candling and breaking was found to be initially from 0.0012 to 0.0021 per cent on the wet basis, and to increase gradually during storage to about 0.0030 per cent in November or December, that is, the seventh or eighth month in storage, and to remain nearly stationary or even to rise slightly until the end of March, the close of the storage period (Tables 12 and 13). Summer eggs entering storage with the same degree of freshness as the spring eggs showed practically the same increase during the same period of holding. In samples having a high initial percentage of ammonia, for example, Experiment 41923 in Table 13, the slowing down in the production of ammonia seemed to occur sooner than in the case of the better quality eggs. This may, perhaps, be explained by the chemical change which took place before the eggs were stored. The amount of ammoniacal nitrogen in the summer firsts and seconds was less consistent during the different months of storage than in the spring eggs. This may be explained by variations in quality between different cases in the same lot, a condition of frequent occurrence in summer shipments. There was very little difference in ammoniacal nitrogen in samples prepared from cracked eggs and those from eggs with whole shells sorted from the same lot. The evidence seems to show that even though the loss in unmarketable eggs varies with different classes, such as clean, dirty, and cracked eggs, if the eggs initially have the same interior quality, those that do keep show practically the same degree of preservation, judged by physical appearance and the amount of ammoniacal nitrogen present.

Pennington, Hendrickson, and collaborators[2] found that during a storage period of six months there was no change in the dextrose in eggs, provided they were not infected with bacteria. In unpublished studies by these investigators, it was found that even up to 10 months storage the dextrose content remained constant.

ABSORPTION OF FOREIGN FLAVORS DURING STORAGE.

It has been found that under commercial conditions a characteristic unpleasant flavor, commonly termed the "cold storage taste," develops in eggs which have been held in cold storage for several months. It is especially noticeable when the eggs are soft boiled or poached. The flavor is not as marked in the white as in the yolk which contains a large percentage of fat. It is known that fats have an affinity for odors and flavors. The facts indicate that the "cold storage taste" is due to the absorption of surrounding odors. When closed the storage room itself has some odor, as have also the

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[1] The determinations of ammoniacal nitrogen in these samples were made by G. C. Swan, according to the methods described in the Journal of Industrial and Engineering Chemistry, Vol. 10, No. 8, p. 614, August, 1918, "Determination of Loosely Bound Nitrogen as Ammonia in Eggs," by N. Hendrickson and G. C. Swan. A forthcoming publication will give the bacterial findings, also determinations of ammoniacal nitrogen in large numbers of individual eggs during various holding periods in cold storage.

[2] Jour. Biol. Chem. (1915) Vol. 20, p. xxi, Proceedings of the American Society of Biological Chemists.

cases and excelsior, but the strawboard fillers and flats possess an odor more nearly resembling that found in storage eggs. The fillers and flats become slightly damp in storage, due to the absorption of moisture evaporating from the eggs and the air of the room, and acquire a stronger odor than when dry. Experiments which will be described in connection with another investigation show that when eggs are protected from air by immersion in a preserving liquid and held in cold storage, the typical "cold storage taste" does not develop. This shows almost conclusively that the "storage taste" is a foreign flavor absorbed by the eggs.

Dirty and cracked eggs absorb this flavor more quickly and to a greater extent than do eggs with clean shells. Although summer eggs usually do not keep as well in storage as spring eggs, they are preferable in winter from the point of view of flavor, because they have not been held in storage as long as the spring eggs. A "storage" flavor can usually be found in April stock in November, in May eggs in December, in June eggs in January, and in July eggs in February.

SUMMARY.

(1) Practically all the eggs used in these investigations were produced in the Middle West and all were stored in warehouses located in the East.

(2) Freshly laid eggs with clean whole shells that have not been wet show a negligible loss in bad eggs, even after 10 to 11 months in storage.

(3) Imperfections in commercial handling, grading, and marketing previous to storage are mainly responsible for the bad eggs developing in commercial eggs during storage.

(4) The preservation in the shell of undergrade eggs, such as dirty, cracked, leaking, heated, and stale eggs, should not be attempted. If not marketed for prompt consumption, the contents should be removed under proper conditions and frozen. The frozen product will keep for a year or more, whereas there would be a marked deterioration in quality, if the eggs were stored in the shell.

(5) Spring eggs on the market are usually fresher than summer eggs, and for that reason keep better in storage. Most of the eggs stored are produced in the spring.

(6) The commercial selection by inspection and clicking of clean eggs with sound shells from current receipts is inefficient. Commercial packages of spring firsts when ready to be taken to the storage rooms showed an average of 17.5 cracked eggs and 1 leaking egg to the case. Dirty and stained eggs were often included. Owing to the high quality of spring stock, there was usually less than 1 bad egg to the case initially present as found by candling.

(7) Candling is a much more accurate method for the selection of eggs for storage. By this method eggs can be graded according to

quality; cracked eggs can be more accurately detected and eliminated; and bad eggs can be found and rejected. Cases of spring firsts graded by candling did not average more than 3 cracked eggs per case when ready for storage.

(8) Spring eggs prepared for storage by commercial sorting showed after 7 to 11 months' storage an average total loss of 18.5 bad eggs per case, 13.5 of which were detected by candling and 5 by breaking. Corresponding cases of eggs graded for storage by candling showed after a similar period in storage 4 bad eggs per case as found by candling and 3 additional by breaking. The value of the good eggs saved by the careful candling of eggs for storage more than offsets the extra cost of preparation.

(9) Of the average of 18.5 bad eggs per case present in the commercially graded spring packages after long storing, 9 were due to direct spoilage of damaged eggs or to their contamination of neighboring eggs by molding. The deterioration of the balance of the eggs with whole shells was no doubt due to deleterious pre-storage conditions, such as dirty, wet, stained, or washed shells, or heated shell contents. Careful grading of eggs for storage very largely eliminates the loss due to damaged, dirty, or stained shells.

(10) The rate of evaporation of moisture from eggs was remarkably uniform during the storage period, and averaged from 3 to 4 ounces per case per month in the different storage rooms under observation.

(11) The moisture from the eggs is condensed on the brine pipes, and absorbed by the air, case, and fillers. Most of the absorption of moisture by the egg package occurs during the first few months in storage. In these studies the gain in weight of individual cases with the accompanying cushions, fillers, and flats varied from 11.5 to 14 ounces during a storage period of 10.8 months.

(12) In the cold-storage rooms under observation there was a gradual rise in the humidity with the advance of the season.

(13) Eggs that are fresh when stored show after storing an increased air space and often a tinge of yellow in the white. The yolk membrane is slightly weakened, but commercial separation into white and yolk is usually easily accomplished, even after 11 months' storage.

(14) The percentage of ammoniacal nitrogen in eggs increases during storage, the rise being the fastest during the early part of the storage period. The amount of ammoniacal nitrogen in eggs is a good index of chemical deterioration.

(15) During commercial holding in cold storage the eggs develop a characteristic "cold-storage taste," which is usually present after the seventh month and becomes stronger the longer the eggs are stored. The evidence seems to indicate that the flavor is due to the absorption of the odors from the surrounding environment, particularly from the strawboard fillers in which the eggs are packed.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE PRODUCTION AND MARKETING OF EGGS.

Natural and Artificial Incubation of Hens' Eggs. (Farmers' Bulletin 585.)
Community Egg Circle. (Farmers' Bulletin 656.)
Marketing Eggs by Parcel Post. (Farmers' Bulletin 830.)
Bacteriological and Chemical Study of Commercial Eggs in Producing Districts of Central West. (Department Bulletin 51.)
Study of Preparation of Frozen and Dried Eggs in Producing Section. (Department Bulletin 224.)
How to Candle Eggs. (Department Bulletin 565.)
The Installation and Equipment of an Egg Breaking Plant. (Department Bulletin 663.)
The Prevention of Breakage of Eggs in Transit When Shipped in Carlots. (Department Bulletin 664.)
Efficiency of Commercial Egg Candling. (Department Bulletin 702.)
Winter Egg Production. (Secretary's Circular 71.)
Marketing Eggs Through the Creamery. (Farmers' Bulletin 445.)
Shipping Eggs by Parcel Post. (Farmers' Bulletin 594.)
Eggs and Their Value as Food. (Department Bulletin 471.)
Variation in Annual Egg Production. (Bureau of Animal Industry Bulletin 110, pt. 1.)
Seasonal Distribution of Egg Production. (Bureau of Animal Industry Bulletin 110, pt. 2.)
Improvement of Farm Egg. (Bureau of Animal Industry Bulletin 141.)
Care of Farm Egg. (Bureau of Animal Industry Bulletin 160.)
Preliminary Study of Effects of Cold Storage on Eggs, Quails, and Chickens. (Bureau of Chemistry Bulletin 115.)
Bacteriological Study of Shell, Frozen, and Desiccated Eggs, Made Under Laboratory Conditions at Washington, D. C. (Bureau of Chemistry Bulletin 158.)
Deterioration of Eggs as Shown by Changes in Moisture Content. (Bureau of Chemistry Circular 83.)
Practical Suggestions for Preparation of Frozen and Dried Eggs, Statement Based on Investigations Made in the Producing Section During Summer, 1911. (Bureau of Chemistry Circular 98.)
The Handling and Marketing of Eggs. (Yearbook Separate 467.)
The Effect of the Present Method of Handling Eggs on the Industry and the Product. (Yearbook Separate 552.)